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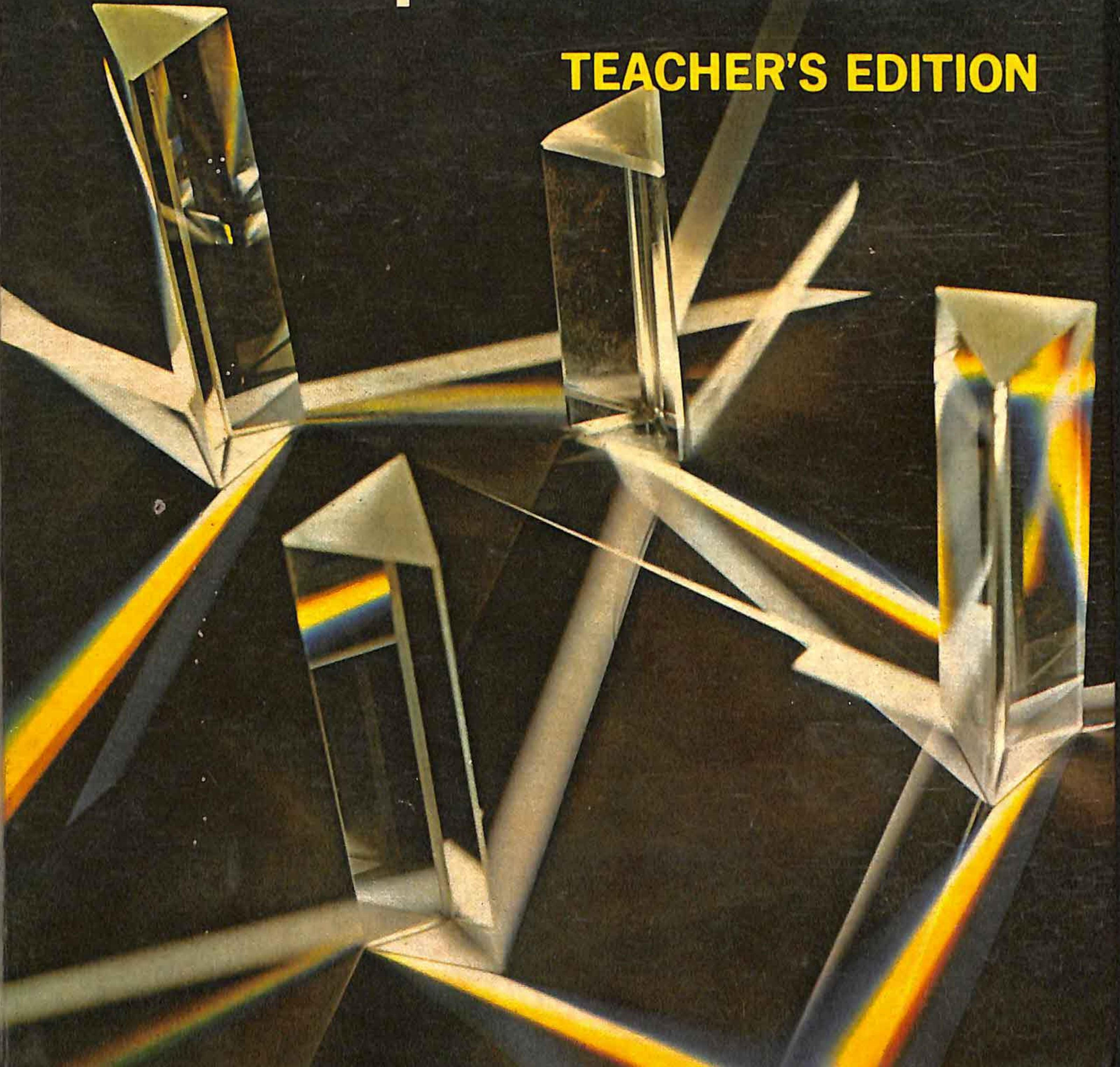

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Concepts in SCIENCE

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° The work of Paul E. Blackwood on the *Concepts in Science* Series was done in his private capacity, and no official endorsement by the Office of Education is intended or should be inferred.

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The child's textbook contains 42 investigations which are integral to the building up of basic concepts in science. Some of these investigations can be performed with the use of readily available materials. Others require simple equipment or materials that normally are less easy to obtain. *Classroom Laboratory 4*, described fully on pages F-17—18, supplies in conveniently packaged form much equipment and materials not usually available locally. A listing of the investigations follows, with the page number of the child's textbook and a symbol which indicates that one or more items for the investigation are available in the *Classroom Laboratory*.

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Part One: CONCEPTS IN SCIENCE Series

The Teaching of Science

A class of sixth-grade pupils was making a tour of the school grounds with their teacher to note the kinds of machines being used in the construction of an addition to the school. With enthusiasm they commented on the cranes, derricks, and bulldozers that were moving earth and construction materials around. As they stopped near some heavy planks and a pile of building stone, the teacher said, "I can invent a machine with these materials so that the smallest one of you can easily lift two of the heaviest." Some of the pupils grinned with disbelief; others were more vocal. Two or three, proud and impatient with knowledge, offered the solution, "You're going to make a lever." But still there was skepticism. The teacher selected a stone, arranged one of the heavy boards over it, asked two of the larger pupils to stand on the end that was nearest the stone, and then selected one of the more vocal disbelievers to lift the two pupils. Of course, the invention worked. The lever multiplied the force of the smaller pupil, as many machines do.

How do machines work? The pupils returned to the classroom, which was now a laboratory. There, during the course of a number of days, they made models of different kinds of machines, investigated how they multiplied force or changed the direction in which the force was applied or increased speed. They invented variations on machines that would multiply the force of muscles and they combined them. They performed mathematical calculations and arrived at certain relationships. At one point, the teacher connected a coil of wire to a dry cell, inserted an iron spike, and picked up a pile of steel tacks. From there the class proceeded to study how inventive persons who understood concepts of science found ways to substitute other sources of energy for man's muscles. During all these investigations the pupils tested their understanding. They collected and recorded data. They used books to check their observations. They interpreted their data and exchanged views of their interpretations. They were, in short, engaged in the processes of science. They were also engaged, as we shall see, in the process of concept-seeking and concept-forming. And they were also using their minds to invent ways to use concepts in doing the world's work.

Now, none of what was done in this school yard and classroom will seem unusual to the imaginative teacher. What is of consequence to teachers and curriculum makers (and writers) is that such experiences should not become merely isolated parts of teaching science, that indeed, in the teaching of science, there should be a structure that is sound in itself. What the teacher was doing with the lever in the school yard and in the classroom was to use technology (in this instance, a lever and fulcrum) to create a situation through which children discovered concepts of science. We prefer to say that a good teaching program *uncovers* the concepts of science. Piaget's classical statement on this subject amounts, eventually, to this: the teacher creates situations through which children discover structure. By "structure" he meant relationships or likenesses among objects and events. A concept is a grouping of relationships, of likenesses, which explains objects and events in the world about us. Each of us tends to uncover the relationship at some particular time, but of course the relationship had been operating in the world before we came on the scene. A concept is new only to scientists, or to us, or to the children. The teacher's art lies precisely in the creating of situations through which children uncover concepts. This appears to be a plain and clear prescription, but of course there are some extremely complex problems confronting the teacher.

There is, obviously, the weight of the teacher's responsibility in teaching science today. In the second half of the twentieth century, children are born in a science-oriented world, in a culture that puts an extraordinary premium on scientific thought and on scientific production. It is sensible to predict that most jobs in the future, including that of teaching, will call for scientific orientation of one degree or another. Contemporary-minded teachers must teach science because society demands it. Helping children to undertake a progressively more sophisticated intellectual activity is a central function in teaching, and creating productive situations—that is, the learning environment—is the teacher's day-to-day responsibility. It is, in many respects, an awesome one. Which situations—of all the countless ones that might be created—is the teacher to select? How is she to cope with the incredible diversity of scientific information, and indeed, with the diversity of children themselves?

From the time children are born, they watch, smell, feel, and listen: they are sentient to the objects and processes of the world. What they know largely derives from their senses and from their perceptions and from the number and kinds of experiences they have had. They acquire meaning, whether true or false, from many kinds of experience—in the classroom, in backyard play, in the streets, in the kitchen, in solitary reflection. They ask questions and examine things and ask still more questions. Because among individuals sensory perception varies and because human experiences vary in both kind and number, no two children begin school with the same knowledge, or with the same set of experiences. It cannot be presumed, therefore, that within the school framework they will move with equal speed or along precisely similar lines of growth. Some kind of provision has to be made to accommodate children of varying experience and of varying ability, and that provision is not alone concerned with the broader questions of homogeneous grouping in schools or of an ungraded curriculum; it is also concerned with providing a scientifically sound structure of learning and teaching science that enables children to uncover the concepts of science in an orderly (though not overly prescriptive) way and at a pace of their individual competency.

A structure in the teaching of science is needed not only to accommodate the phenomenon of diversity in children but also to manage the diversity of the content of science. Scientific research papers are currently being published at the rate of 67,000 words a minute! That amounts to a body of information that would fill eleven sets of a thirty-volume encyclopedia every twenty-four hours. Quite obviously, unless an attempt is made to evaluate, to select, and to sort new information into some kind of structure for the classroom, teachers will fall further and further behind. There is, moreover, the necessity to recognize that scientific knowledge, while it proceeds from facts, is not in itself the mastery of facts. Facts become meaningful, and the awareness of facts ultimately becomes productive, when they are perceived within the structure of basic concepts. We may modify George Gaylord Simpson's definition of science slightly. *Science is the exploration of the material universe for the purpose of seeking orderly explanations of objects and events, explanations that must be testable.* The products of science—which are its orderly explanations and the technology that results from the particular application of them—are the results of certain processes. The processes comprise, first, the observation and examination of data, including experimentation; second, the formulation of explanations by means of inventing hypotheses and stating theories; and third, the testing of the explanations. But the product of all this, the explanations, leads inevitably to other explorations and still other explanations. There are ends in science, but there is no end to science itself.

In their activity, scientists engage in concept-seeking and in concept-forming, and as a matter of course, in concept-testing. This is clearly a function of scientific inquiry. But what do children do when they are engaged in scientific activity? They explore the material universe (observe a plant grow, observe an object move down an inclined plane, observe a balloon that has been untied shoot through the air) and they seek orderly explanations of the objects and events they observe. They also investigate, and where possible, they might even experiment (although in a school context it is most difficult for students to perform an experiment in the *pure* sense simply because all the variables are difficult to control). They verify the data obtained from observations and they seek to interpret the data. They seek to predict results on the basis of the knowledge they have gained. They attempt to uncover explanations that reliably relate seemingly disparate or "discrepant" objects and events, and that will make prediction of other events possible. They are engaged in understanding concepts of science and in applying them to the world about them.

Identifying the basic concepts of science is not the discrete task of the teacher. The teacher has the right to expect that she will be given help in identifying concepts and in forming a structure for the teaching of science, and this is a shared responsibility that the *Concepts in Science* authors and publisher, and the scientists and teachers who have advised them, have accepted. They recognize that school is time-binding, that work goes on in a certain time span—grades, terms, years—and that many teachers share in the development of each child. They know that a teacher must have a notion of what school experiences children have had before they come into her ken, as well as what will follow once they leave her. The need for a curriculum in science which gives the teacher scope and flexibility is plain enough; what is sometimes not so plain is the need for a curriculum that has a scientifically sound and pedagogically sound structure. We have attempted to give structure to the teaching of science during the first nine years of schooling by informing the processes of science with an understanding of the concepts. We have, in short, sought to identify and define a structure that is not only verifiable scientifically but also viable (practical, productive) in teaching. The conceptual approach is central, in our view, to both aims, both to sound science and sound teaching.

A Modern Science Curriculum

Early in the twentieth century the school curriculum in the United States tended to be content-centered, or disciplinary. During the twenties and thirties this curricular approach gave way to a so-called child-centered approach; the emphasis was shifted—this is overstated for purposes of simplification—from the subject to the learner. Today, still another shift is occurring as content is being placed in a stronger and more relevant role in the curriculum. More and more the emphasis is placed on the interrelationship, more specifically the interaction, between the discipline and the pupil in the learning act. Again with some oversimplification, the contemporary curriculum can be said to be process-centered. Certainly this is apparent in science teaching, and the advance of this kind of curriculum has been most directly aided by the involvement of scientists in the elementary and secondary schools. They have been enormously helpful in proposing a teaching structure for the early school years of science study.

Within the various disciplines of science—biology, chemistry, physics, geology, etc.—data accumulate and change at a bewildering rate. Change is constant. Yet the concepts of science—which are a patterning of facts and a statement of the relationships between observable events and objects—are relatively stable. In a changing world, concepts offer, for this and other reasons, a reasonable foundation for the building of a science curriculum. They are, in a true sense, guides as well as aids to learning.

All of us have the task of sorting out events that come to our awareness in haphazard sequence. All of us have the task of discovering which of the objects and events we perceive are significant and which are not. To bring order out of our haphazard perceptions, we tend to seek a grouping of likenesses among a number of objects and events perceived; in short, we tend to seek concepts. To form a concept, we assort or group objects and events according to their attributes and properties, and we define categories. An example of what is meant by the "attributes" of an object or event will be useful.

A stone has shape, color, weight, and the like; these are some of the attributes of a stone. A bird also has shape, color, weight. Yet there are other attributes of the stone—for example, immobility and hardness, which we recognize as part and parcel of "stoneness." A bird, on the other hand, has mobility, it has feathers, it has egg-laying propensities, and it has a certain structure (from beak to tail)—these and other attributes we recognize as essential to "birdness." In forming a concept, the brain selects those essential attributes (those which discriminate one object from another) which signal the whole configuration of the object or event. Thus the weight of an object is generally not an essential or discriminatory attribute; an attribute of a weight of one pound might apply to a one-pound chicken or a one-pound stone. But "feather" or "beak" is a signal, or cue, for categorizing or concept-forming. It is a signal of the whole concept of "birdness" and it enables us to fill in certain other essential attributes.

Now in learning, the *act of concept-forming* enables an individual to infer; from a few signals or cues he can infer a significant grouping, or category, of like attributes. These signs or cues can be related to *objects* (stones, birds, simple machines) or to *events*, such as the changing of one form of energy to another (for example, the friction of the hands resulting in heat, or the reproduction of organisms, or the splitting of an atom). A specific example in the teaching of a concept, in developing the ability in children to group the like attributes of an event, can be given here. Suppose we wished to create situations through which children would uncover the events that can be grouped within the concept: *Living things capture matter from the environment and return it to the environment*. This is precisely the objective of Unit Five of *Concepts in Science 4.* A series of seven lessons is organized in a sequence in which situations are created whereby children come to *associate* an entire set of attributes of this event: *Living things capture matter from the environment and return it to the environment*. Even if children were to undertake the performance of only the six investigations in the unit, they would be engaging in the selection of essential attributes of the event. This would enable them, in turn, to predict the event from one signal, say, a fuzz of mold on a lemon. But the text suggests activity after activity—seeds are grown, soil minerals are investigated, starches and sugars are examined, the energy needs of green plants are studied, the growth of a plant is traced, and the process of decay is analyzed. Perhaps you would care to examine Unit Five now for a fuller exposition of the way the text assists the teacher in creating situations through which children engage in concept-seeking and concept-formation. But, of course, the text is only a part of a very rich program of science in which process is central (see pages F-16—F-18).

In brief definition, then, *a concept is a mental construct; it is a grouping of the common elements or attributes shared by certain objects and events.* Once a concept is attained, economy in future learning is also attained. For by engaging in the processes of concept-formation, the learner is active in selecting the essential attributes of the complete event, such as "Living things capture matter from the environment and return it to the environment." And the learner is enabled to predict an entire sequence of events, or an entire set of characteristics or properties, from a small number of cues or signs. Thus, a fuzz of mold on a piece of fruit or on moist bread is a cue signalizing an entire event.

Defined in other words, a concept is a network of inferences stemming from observation of objects and events, and resulting in the selection of common elements, or like attributes, among the objects and events under observation. Identifying and organizing the common, or like, attributes results in a significant category or grouping. That significant category is a concept. A concept is practical and useful because the perception of a small number of attributes, cues, or signals, brings the whole object or event into satisfying recognition. To repeat, a mold growth brings to mind the object (a living thing) and the event (the normal life cycle of growth and decay).

Because we are teaching children, it is well to *group* experiences in a way which will enable teachers to plan their work sequentially. Hence we have ordered the *concept structure of the curriculum you have in hand*. It provides for small blocks of experiences, dealing with objects and events with similar attributes which young children can handle. We have attempted, moreover, to develop a curricular structure which bears some correspondence to the school year, day, and period. Further, for purposes of readier facility in planning the work of the first six years of elementary school, we have grouped a given series of concepts under a still larger category which we call a *conceptual scheme*.

Conceptual schemes provide, we believe, a framework within which the teacher can provide experiences that will lead students to participate in the processes of science—in observation and in interpretation—and emerge with the products of science, which are testable explanations of the workings of the material world. This seems to be a large order. It is. The authors and publisher have spent eight years in the preparation of the curricular organization and materials in this program. They have tested their performance during hundreds of hours in typical classrooms. It is their belief that the conceptual approach is a feasible one that will produce excellent results. In an ultimate sense, their aim is to help the teacher produce an interaction between discipline and student, between the subject and the learner. For this reason, content is never skimped. For each grade there is a hard core of content or subject matter that exceeds more than even the bright child will be able to encompass in the time he is generally allowed.

What has been done in this program, then, is to lay out a framework of conceptual schemes through the first six years of schooling. The framework is capacious. It does not fix the teacher or the student into an inflexible curriculum. On the contrary, it gives the teacher freedom to plan a variety of experiences and it gives the student freedom to plot his own experiences. In both instances, however, the experiences will be ones which are relevant to a search for meaning rather than for the random acquisition of facts. In a real sense, understanding is made simpler for children when they are able to conceptualize—to see patterns in their environment, to group objects and events on the basis of their common elements. A program that accomplishes this is essentially an economical one, economical in the time that is spent in learning. Because, as has been said earlier, concepts remain relatively stable, concepts provide an organization of information that is relatively stable. New observations, new data, variant experiences can all be fitted into the conceptual framework.°

Teachers in St. Mary's County, Maryland, have been experimenting successfully with an elementary science curriculum based on conceptual schemes. Their course of study, initially developed by a curriculum committee, is now in its sixth year of development. Similar courses of study have been developed by other schools and school systems, particularly the Nova School, Fort Lauderdale, Florida.

If we interpret the psychology of learning (so far as it has advanced, which admittedly is not far enough!) with any degree of acuity, then we assume that it is important for children to learn in "wholes." In this sense, concepts are "wholes." Moreover, if we accept the definition that education should result in a change of behavior in the student, then an understanding of concepts will provide a person with intelligent means of deciding among alternatives. The conservation of natural resources; the support of public health programs; the questions of population growth; the fallacies in ethnic discrimination—all these are civic and social matters that confront a contemporary person. He is better able to judge what he perceives, and better able to support what he believes, when he understands the basic scientific concepts. The teaching of science ought to do more than dispel ignorance and superstition; it ought to help provide means by which a human being can comprehend what is today known but still unseen or still not widely operative. Exploration of the moon is a certainty, even though it has not yet happened.

The *Concepts in Science* series is an elementary science curriculum which attempts to reflect commonly accepted and basic ideas of contemporary scientists, cognitive psychologists, and teachers. It is a systematic organization of instructional materials. It is also a laboratory-centered program. The framework of six conceptual schemes provides a learning sequence that is shown, in broad outline, on the chart on pages F–14 and F–15. The sequential development is represented on the chart as horizontal threads called *concept levels*, which increase in complexity as one advances from one level to the next.

The National Science Teachers Association Committee on curriculum development, in "Theory in Action," ° suggests seven conceptual schemes. The Committee agrees upon twelve statements. Seven of these statements discuss conceptual schemes, and five of them describe the process of science as the base for science curriculum planning. In the *Concepts in Science* series, the concepts have been grouped under six conceptual schemes, but the differences between this organization and that of "Theory in Action" is not substantial or finally consequential. The authors suggest that the content of the science curriculum could be arranged in an orderly structure under six conceptual schemes in a way that effects economy in organization, time, and effort.

° See *A Study of Thinking* by Jerome S. Bruner, Jacqueline J. Goodnow, George A. Austin, John Wiley & Sons, Inc., New York, 1956.

° Published by the National Science Teachers Association, 1964.

A Comprehensive Program

The major conceptual schemes can be stated in somewhat arbitrary terms; no doubt, different teachers will state them differently. Certainly they would be stated differently for the scientist-specialist than for the elementary-school teacher, who of necessity teaches not only science but English and social studies. Certainly the statements may be modified and restated under different conditions, with different pupils, and in different schools. Yet the authors have chosen to state the conceptual schemes in terms that can be used throughout the particular content and activities in the *Concepts in Science* series.

A Framework of Conceptual Schemes

The conceptual schemes and the general areas they subtend are:

1. When energy changes from one form to another, the total amount of energy remains unchanged.

Energy transformation is a common phenomenon. If you rub your hands, mechanical energy is converted to heat energy. If you burn a candle, chemical energy is converted to heat and light; and in a dry cell, chemical energy can be converted to electric energy. But whether one is concerned with burning oil in the home, gasoline in the automobile, glucose in the body, or whether one is concerned with the transfer of the energy of moving water into a flow of electrons in a conductor, the total amount of energy in any given system remains unchanged. This conceptual scheme is a primary concern in the discipline of physics.

2. When matter changes from one form to another, the total amount of matter remains unchanged.

The world of matter consists of a world of things, from the very large bodies—stars, planets, moons, and other celestial bodies—to the very small particles—atoms, molecules, and subatomic particles. As the matter in the universe undergoes physical change, a change of state, and chemical change, a change in form, the total amount of matter undergoing chemical or physical change in any given system remains unchanged. This conceptual scheme lies within the discipline of chemistry.

3. Living things are interdependent with one another and with their environment.

Around living things everywhere, there exists an environment of matter and energy; indeed, living things cannot be considered apart from their environment. Plants depend upon their environment for their growth and development. Green plants capture energy from the Sun in the photosynthetic process; animals, in turn, transform the chemical energy of plants. And finally, all plants and animals yield their matter and energy as they die and decay. In addition, the demands of living in a given environment result in a relationship between plants and animals in communities that display definite characteristics—deserts, forests, seas, ponds, etc. For example, the sea is an environment in which ninety percent of the world's photosynthesis takes place, where complex food niches are developed, and intricate reproductive cycles operate. Understanding these interrelationships results in our ability to predict, within limits, the behavior and development of plants and animals. The conceptual scheme that describes them is a part of the study of biology.

4. A living thing is the product of its heredity and environment.

Within this conceptual scheme, one can develop the concept of an organism that lives in a kind of dynamic equilibrium. The organism is never the result purely of its heredity but of the environment interacting with hereditary factors. This is true of any specific trait. This is also important to comprehend in a human being's realization of full physical development and vigorous health. Other examples:

A red barberry is greenish unless exposed to strong sunlight.
An intelligent child needs an education.
Beets in acid soil are stunted.
A child lacking vitamin B may develop beriberi.
A potato seedling in the dark is attenuated.
A child poorly fed and poorly housed does not resist tuberculosis as well as one who lives in a more salutary environment.

The full range of the development of organisms—including the study of reproduction, genetics, growth, nutrition, behavior, and adaptation to the environment—is involved in this conceptual scheme, which is the concern of several sciences: genetics, physiology, and biochemistry.

5. Living things are in constant change.

The universe changes; the Earth changes; the single organism and the species change over the ages. The concepts of adaptation over the ages, divergence in form, convergence in geographical isolation, and evolution are within the purview of this conceptual scheme, which involves genetics and ecology.

6. The universe is in constant change.

Every child today seems to know that the solar system is changing. Certainly the earth's atmosphere is constantly shifting. The Earth is in constant motion; the Sun is in constant eruption. We note the appearance of novas and supernovas. We observe and gain evidence from Cepheid variables. We interpret the red shift in starlight to indicate an expanding universe in constant change. The change in the universe comprises a conceptual scheme that is the primary concern of geology, astronomy, and meteorology.

A Developmental Structure of Concepts. Expectedly, as the concepts in science are selected to fit the purposes of instruction in the elementary school, they seem to group themselves easily. The rationale is this: first, concepts should fall easily into a particular conceptual scheme; second, they should be ordered from the simple to the complex. "Simple" is used here in the sense that the experiences provided should be simple. Young children do not deal with a complexity of cause and effect, that is, with *multiple variables*. For example, it is fairly easy in the second grade or level to deal with the concept *related living things reproduce in similar ways*. On the other hand, the concept *the characteristics of a living thing are laid down in a genetic code* requires that we make available more complex experiences which are appropriate at higher levels. All this is not to imply that some children cannot deal with more complex structures even while the norm for a class is said to be a concept development at a lower level. A particular advantage of a conceptual structure in the curriculum is the provision for extended or accelerated growth in individual children. For instance, if a child seems to understand a concept at a higher level of complexity than his classmates, the teacher can determine the level of understanding by asking appropriate questions at a lower concept level (pages F–14—15). If a sufficient number of children are able to deal with a higher concept level, procedures may then be modified.

The organization of a curriculum in terms of concept levels accommodates its own "multiple tracking." As a result, it is possible to have groups, or even individuals within the same class, proceed at different rates up the concept "rungs" of the conceptual "ladder." They can engage in experiences which are appropriate to their level of understanding, and at the same time communicate with groups at other concept levels. In other words, they are all on the same ladder, if on different rungs. In any event, a teacher will certainly wish to know the entire conceptual structure. The structure for *Concepts in Science 1–6* is charted on pages F–14—15.

The concepts which form the rungs of the conceptual ladder can be stated in various ways, but the central purpose is to organize them in graduated order so that understanding of one (in a lower level) precedes the next for purposes of greater comprehension and utilization. There is some danger, we believe, in stating a conceptual scheme (or even a concept) by a single term (for example, *energy, matter, life*). However convenient this may seem, such easy rubrics may have the effect of limiting the implications of this approach to science study.

Now, the structure for science in the first six grades of the elementary school, here given as six conceptual schemes, with the concepts given at six levels (not necessarily grades), is purely for convenience and custom. The levels, until research proves this unwise, are in a rough order of precedence. Naturally, each concept has a number of subconcepts; the development of subconcepts depends on the judgment of the teacher.

The essence of science is *investigation of the material universe*. Its goals consist of a search for meaning; indeed Albert Einstein once defined it as experience in search of meaning; it *seeks orderly explanations (conceptualizations) of phenomena, the objects and events about us*. Nevertheless, there is stubborn insistence by scientists that an orderly explanation *be testable*. If a concept is not testable, it is usually not acceptable. Science is, in

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A STRUCTURE FOR

	CONCEPTUAL SCHEME A **When energy changes from one form to another, the total amount of energy remains unchanged.**	**CONCEPTUAL SCHEME B** **When matter changes from one form to another, the total amount of matter remains unchanged.**	**CONCEPTUAL SCHEME C** **Living things are interdependent with one another and with their environment.**
CONCEPT LEVEL VI	The amount of energy gotten out of a machine does not exceed the energy put into it.	In nuclear reactions, a loss of matter is a gain in energy; the sum of the matter and energy remains constant.	Living things are adapted by structure and function to their environment.
CONCEPT LEVEL V	Energy must be applied to produce an unbalanced force, resulting in motion or change of motion.	In chemical or physical changes, the total amount of matter remains unchanged.	The capture of radiant energy by green plants is basic to the growth and maintenance of all living things.
CONCEPT LEVEL IV	A loss or gain of energy affects molecular motion.	In chemical change, atoms react to produce change in the molecules.	Living things capture matter from the environment and return it to the environment.
CONCEPT LEVEL III	The Sun is the Earth's chief source of radiant energy.	Matter consists of atoms and molecules.	There are characteristic environments, each with their characteristic life.
CONCEPT LEVEL II	Energy can change from one form to another.	A change in the state of matter is determined by molecular motion.	Living things depend on their environment for the conditions of life.
CONCEPT LEVEL I	Energy must be used to set an object in motion. There are many forms of energy.	Matter commonly exists as solids, liquids, and gases.	Living things are affected by their environment.
	CONCEPTUAL SCHEME A **When energy changes from one form to another, the total amount of energy remains unchanged.**	**CONCEPTUAL SCHEME B** **When matter changes from one form to another, the total amount of matter remains unchanged.**	**CONCEPTUAL SCHEME C** **Living things are interdependent with one another and with their environment.**

CONCEPTS IN SCIENCE

CONCEPTUAL SCHEME D A living thing is the product of its heredity and environment.	CONCEPTUAL SCHEME E Living things are in constant change.	CONCEPTUAL SCHEME F The universe is in constant change.	
The characteristics of a living thing are laid down in a genetic code.	Changes in the genetic code produce changes in living things.	Nuclear reactions produce the radiant energy of stars, and consequent change.	CONCEPT LEVEL VI
The cell is the unit of structure and function; a living thing develops from a single cell.	Living things have changed over the ages.	Bodies in space (as well as their matter and energy) are in constant change.	CONCEPT LEVEL V
A living thing reproduces itself and develops in a given environment.	The environment is in constant change.	The motion and path of celestial bodies are predictable.	CONCEPT LEVEL IV
Living things are related through possession of common structure.	Living things grow and develop in different environments.	There are seasonal and annual changes within the solar system.	CONCEPT LEVEL III
Related living things reproduce in similar ways.	Forms of living things have become extinct.	There are regular movements of the Earth and Moon.	CONCEPT LEVEL II
Living things reproduce.	There are different forms of living things.	There are daily changes on Earth.	CONCEPT LEVEL I
CONCEPTUAL SCHEME D A living thing is the product of its heredity and environment.	CONCEPTUAL SCHEME E Living things are in constant change.	CONCEPTUAL SCHEME F The universe is in constant change.	

short, the "art of investigation" (Beveridge's term). But one cannot investigate an object or event if the object or event is not first perceived.

This book is literally a sourcebook of situations in which children participate and perceive objects and events. In creating a learning situation, children are given opportunity to seek the attributes of objects and events and to seek hidden likenesses. In the situation described on page F–7, the sixth-grade children engaged in these processes: they *observed* the working of a lever; they *investigated* the relationship between machines and forces; they *collected* relevant data; they *described* the operation of the lever and other simple machines; they *discussed* their results; they *confirmed* one another's results (through collaborating in an investigation); they *read* the work of scientists; they *invented* and then *reported* their results in a kind of colloquium. Note the processes: observation, investigation, collection of relevant data, description of results, discussion of findings, confirmation of findings, reading the work of scientists, exercising inventiveness, reporting of work, and within limits, experimentation, among other processes.

RESOURCES FOR A COMPREHENSIVE PROGRAM

The structure of science and the processes of science yield knowledge and they yield understanding but at no time could they exist without the materials of science—materials which provide the media for investigation, whether the investigation involves reading a textbook or carrying out a sophisticated experiment in the laboratory. The materials for *Concepts in Science* include the facts of science as well as the tools of science. These materials come in the form of reading matter, illustrations, manipulative objects, laboratory guides, testing instruments, and other aids to teaching.

The *Concepts in Science* series provides the whole range of suitable materials for Grades 1–9. It includes basic textbooks for the child, each accompanied by a Teacher's Edition for Grades 1–6 (a separate Teacher's Manual for Grades 7–9); Workbooks for Grades 4–9; packaged equipment for Grades 1–6 called *Classroom Laboratory;* individual investigation cards called *100 Invitations to Investigate;* and *Teaching Tests.* There are, moreover, books available for the teacher.

TEXTBOOKS

Each book in the *Concepts in Science* series is organized to accomplish efficiency in the learning process. Each book is designed to create an atmosphere of discovery in concept development; to stimulate personal involvement; to maintain sharp curiosity; and to lay a firm basis for intelligent action and independent inquiry. The processes of science, as well as its products, are emphasized and yet interrelated as the pupil participates in the act of learning. Each book is illustrated for visual interpretation of objects and events that may or may not be a part of the pupil's everyday experience.

While the full-color photographs and drawings enhance the visual quality of the textbooks, they serve the important function throughout the program of training children to observe with discrimination the pictorial representations of their physical environment. Many of the photographs are of actual performances by pupils and experienced teachers in the classroom.

Each book contains an abundance of investigations to help develop the main concept of a section. As the investigations are self-contained and self-explanatory, except in *Concepts in Science 1* and *2* where the directions are given by the teacher, little discussion of the investigations is given other than to suggest possible pitfalls and to advise on the most profitable time during the lesson to undertake the investigation. Actual photographs illustrate one trial investigation. Since the text does not tell what happens, the photographs serve as guides for the pupil; but the pupil must observe for himself and try the investigation. All investigations have been laboratory tested for effectiveness and for safety.

In addition to the investigations that are found at strategic points within the sections, there are "open-ended" investigations at the ends of the sections as well as at the ends of the units. Each investigation is an extension and addition to the pupils' initial concept formation. Furthermore, these additional investigations point up the fact that many trials are necessary to establish and confirm results of one investigation. End-of-book sections, which progress in difficulty from book to book, stimulate individual investigation that is relatively complex in observation and experience.

Each book in the *Concepts in Science* series features cumulative concept reviews and evaluations which enable the pupils to test their understanding of a concept. These reviews enable pupils, moreover, to apply their understanding to new situations, to hypothesize solutions to a variety of problems, to recognize relationships among concepts, and to infer relationships among conceptual schemes. At every step of the way the pupils are provided with experiences which help them find unity among diversity, to achieve order out of disorder in the objects and events of the world around them.

Concepts in Science builds a precise science vocabulary. Throughout the program, provision is made for growth in vocabulary as it specifically relates to science. In *Concepts in Science 1* and 2, the teacher is encouraged to introduce new words on a science vocabulary chart to be displayed in the classroom. These same words are listed in the back of the child's text for his individual use. In *Concepts in Science 3–6*, key words are introduced in boldface type and repeated, with page references, in the glossary. Definitions increase in depth and extension of meaning from book to book.

The reading vocabulary has been carefully controlled for the grade level throughout the program, with due attention to the adequate presentation of technical vocabulary necessary to understanding concepts in science. In *Concepts in Science* 3 and 4, a pronunciation-at-sight system is used; and in *Concepts in Science* 5 and 6, a standard system of diacritical marking is used.

TEACHER'S EDITIONS

The Teacher's Editions to accompany the *Concepts in Science* textbooks are organized for maximum teaching effectiveness. They contain the background information that teachers need to teach a unit with confidence and enthusiasm which eliminates, for the most part, the necessity for further research on the part of the teacher. The conceptual structure of the curriculum is outlined clearly, and carefully selected activities and experiences are prescribed and described as effective means of concept development.

A comprehensive teaching pattern is apparent in each of the teacher's editions and is analyzed in detail in **Part Two** of the introductory material in each book. For this book, see pages F-19—23.

CLASSROOM LABORATORY

The classroom for science should resemble a laboratory in which children actively work with objects at their own desks or tables, individually and in groups, observing, rearranging, manipulating, investigating, experimenting, testing, and discussing findings and inferences with one another.

The *Classroom Laboratory* for the *Concepts in Science* series is a practical way of converting an ordinary classroom into a classroom laboratory. There is one each for *Concepts in Science 1–6* which is designed to fit the needs of the science curriculum by providing the materials and equipment for pupils to experience science in the classroom. It is built around the concepts of the science curriculum; it anticipates and solves the problems of classroom management, and is designed to be used by the entire class.

While an entirely optional part of the *Concepts in Science* program, the *Classroom Laboratory* deals with investigations that give pupils the opportunity to uncover the science concepts that are developed in the basic textbooks. Part II of the Teacher's Manual which accompanies the *Classroom Laboratory* is keyed by page number to the pupil's textbook. Similarly, the Teacher's Editions are keyed to the *Classroom Laboratory* so that a teacher will know at once if materials are provided for an investigation in *Concepts in Science 1–6*. Part III of the Teacher's Manual for each *Classroom Laboratory* provides for additional investigations that enrich the child's experiences.

Each *Classroom Laboratory* is accompanied by a Teacher's and Pupil's Instruction Manual.

To provide opportunities for an entire class to experience the processes of science, the equipment and materials are supplied in multiples of six, except in the case of certain types of equipment for which one item is adequate for the experience of all the children. A class of 30 pupils, for example, may be divided into six groups of five pupils, with each group performing the same investigation. There are also materials for the performance of numerous individual activities which may be used as teacher or committee demonstrations. Furthermore, the laboratory is so organized that it is possible to find any required material within a few moments and to return it easily to its proper place for future use. Many items are also useful for the activities in the workbooks, described below.

While the contents of the individual laboratories differ, depending on grade level, each one contains a tray of commonly-used apparatus: beakers, test tubes, tripods, plastic tumblers, plastic dishes, and other basic materials which can be reused whenever needed. With normal use, some depletion of parts will occur each year and a small portion of the items are consumable. Replacements are available from the publisher.

WORKBOOKS

Concepts in Science Workbooks, available for Grades 4 through 6, give pupils additional opportunity to reinforce and extend their understanding of the concepts developed in the *Concepts in Science* textbooks. Through the experiences that are provided in these workbooks, pupils review concepts and apply them in new context. New problems are introduced which are related to problems they have already studied, but which differ in some significant way from those in the textbooks. Moreover, the workbooks give additional practice in utilizing basic laboratory skills—recording observations, tabulating data, interpreting data, and drawing conclusions—as well as practice in using scientific apparatus. The activities in the workbooks have been selected to provide experiences in various situations—at home, in the classroom, on a field trip, in the library, or in the laboratory; and from these experiences, pupils are called upon to organize and apply the concepts and skills initiated and developed in their textbooks. Self-testing reviews are included for additional pupil evaluation and a Teacher's Correction Key, separately available, provides suggested answers.

TESTS

Teaching Tests, prepared and screened by the Harcourt, Brace & World Science Testing Board, are available separately for *Concepts in Science 3* through 6. The answer keys are found in the Teacher's Editions of the textbooks.

These tests, to be used after each unit in the pupil's books, go beyond the testing of facts. Like other elements in the *Concepts in Science* program, they help teachers evaluate the pupil's understanding of concepts. The questions for each test are designed to evaluate comprehension as well as retention of information. They are divided into several parts; the parts are designed to test the child's ability to read for comprehension and interpretation, the ability to recall factual information, the ability to evaluate and apply concepts in new situations. They may also determine how well the pupils perceive relationships among the concepts developed.

LABORATORY CARDS

100 Invitations to Investigate, a set of 100 ungraded laboratory cards, provide the background information, illustrations, and clues to procedure for pupils' independent investigations. The investigations are a random assortment in the biological, physical, and chemical sciences; they progress in difficulty—the higher numbered investigations being more sophisticated. The cards, which are packaged in a sturdy case, are designed for those pupils who wish to pursue, beyond what is covered in the textbook, their own interest in some particular area of science, independent of their regular classroom work. Each child is encouraged to select the investigation in which he is interested, to investigate with enthusiasm and imagination, to seek answers to problems for which his textbook offers no solution. While designed for enrichment, the laboratory cards also lend themselves to science study by specially interested students and for science in ungraded programs.

SOURCEBOOKS FOR THE TEACHER

Harcourt, Brace & World publishes a number of professional books which provide supplementary information for teachers on how to plan, prepare for, and carry out a science program in the elementary school. Written by specialists in the field of science education, these books provide the "tactics and strategy" as well as the techniques for teaching elementary and high school science. They also employ the scientific and educational psychology involved in the teaching of science. You will find a list of these publications on the first page.

Part Two: CONCEPTS IN SCIENCE 4

Structure and Content

Concepts in Science 4 is more than a series of related sections in eight units. It is more than a sum of its separate parts. It is the fourth in a series of six books of an elementary science curriculum. It is a part of a sequential and fully articulated program in which each unit has dependence upon the content of units previously studied. Each section in the textbook is part of the larger pattern of the unit. The unit, in turn, is part of a still larger pattern, the year's work in science, which encompasses the six conceptual schemes at the concept level indicated on pages F–14—F–15.

Science concepts are interrelated. Energy, for instance, is introduced in Unit One in relation to the study of the travel of sound waves and in Unit Two in relation to the study of light. In later units, energy is reintroduced and reused in relation to evaporation and condensation, oxidation, matter and its forms and states, the cycle of growth and decay of plants and animals, erosion and sedimentation, and the orbiting of the Moon, comets, and other bodies in space. The concepts of matter and interdependence are similarly introduced, reintroduced, and reused in more than a single unit.

The conceptual schemes set forth in this Teacher's Edition, and the subconcepts which serve them, lend themselves to basic experiences for children as they study the objects and events in their world. A concept learned in one unit is recalled and reapplied in new context in later units.

In *Concepts in Science 4* the eight units develop the fourth level of the six major conceptual schemes. Each unit is primarily concerned with one conceptual scheme, but some schemes appear in more than one unit. The eight units, after a study of sound and light, and atoms and molecules, deal with a variety of cycles: the water cycle, the carbon dioxide-oxygen cycle, the growth and decay cycle, erosion and mountain building, and the cyclical return of heavenly bodies in their orbits—to give but a partial listing. Yet, to the scientist, these units are concerned with only three categories: energy, matter, life. These three categories have been studied in earlier textbooks in the series and will be studied again on succeeding levels of increasing sophistication in relation to what the authors have chosen to call the six major conceptual schemes—schemes that are basic to the child's understanding of the material universe.

Earlier concept levels for each conceptual scheme are basic to understanding the scheme as it is developed on this and succeeding concept levels. *Concepts in Science 4* builds upon earlier levels. The conceptual schemes are not *taught* to the children; rather, they are the eventual goals the children, as learners, reach through experiences selected to provide a maximum of individual involvement in the learning process. Concept formation proceeds step-by-step through all the grades.

The exploration of the environment, certainly a major aim of science, does not begin in the first grade, nor end in the fourth. Most young children enter school with a fund of science information (and misinformation) and a fairly well-developed pattern of behavior that has served their need to satisfy their natural curiosity. By the fourth grade they have had new experiences, many that have been planned in search of meaning. In school, their experiences have been selected and organized for conceptual understanding, a necessity if the search is to be successful.

In each grade, teachers help children to organize and evaluate their information, and to use and improve their habits and skills of investigating. Their investigating, however, proceeds no longer in the random fashion of early childhood; rather, it proceeds through thoughtful selection of the processes of scientific investigation in a sequential, developmental pattern of experiences systematically organized as a science curriculum. Let us examine the pattern in *Concepts in Science 4*, as it is developed in the textbook and Teacher's Edition.

THE STRUCTURE OF A UNIT

All the units in the child's textbook have the same structure and the same component parts. All the units in this Teacher's Edition exactly parallel the structure of the child's textbook, except, of course, that the statements of the conceptual goals of the teaching and learning processes are not included in the child's textbook. All the teaching suggestions for each unit directly precede the reproduced pages of the child's textbook and are readily identifiable by the color bands on the outside margin.

Since you will be starting with Unit One, "The Bounce of Sound," a brief analysis of the teaching suggestions on pages T–1—T–17 will serve to explain the main headings and help in developing an approach to teaching the sections in this and subsequent units.

Across the top of page T–1 is a statement of the **Conceptual Scheme** followed by the **title of the unit** and a notation of the pages of the child's textbook to which the teaching suggestions refer. In the margin appears a statement of the **Unit Concept.** Reference to the chart on pages F–14—F–15 shows that this Unit Concept for Unit One thus deals with Concept Level IV of Conceptual Scheme A. Similarly, other units are seen directly to fit the same concept level of one or another of the six conceptual schemes.

Next to the Unit Concept statement is an interpretation for the teacher that is related to questions children are likely to ask, observations they may make, or procedures they will use in working toward the goal of concept formation and conceptual understanding.

In "A View of the Unit," which immediately follows the title of the unit, it is recognized that teachers have many claims upon their time and energies. This preview of the concepts not only summarizes the subconcepts that supply the evidential base for the unit concept, but also provides background information that often goes considerably beyond the fifth-grade level. It is hoped that this introduction will render it unnecessary that a teacher do further research before beginning to teach the unit with confidence and enthusiasm.

Under "Supplementary Aids" (see pages T–2—T–4), there is a graded listing of films and filmstrips for classroom showing, as well as books for the science reading table. The films and filmstrips have been previewed, selected, and rated by Bess S. King, formerly supervisor of Santa Monica Public Schools, Santa Monica, California. A "primary" rating indicates that the concepts are relatively easy to comprehend, while a "junior high school" rating indicates they are relatively advanced for fourth grade, but useful if their presentation is carefully guided. The books suggested for the science reading table were reviewed, selected, and graded for reading level and conceptual content by Ester K. Nelson, Consultant in Elementary Education, Bureau of Elementary Education, California State Department of Education, Sacramento, California. The authors of *Concepts in Science* unhesitatingly concur with the choices. The *Classroom Laboratory* and other items for a comprehensive program are described on pages F–17—18.

Suggestions for **Introducing the Unit** (see page T–5), together with the opening two pages of the unit in the child's textbook, serve to stimulate curiosity and link thought to action. They lead directly into the teaching suggestions for Section 1 of the unit.

The Pattern of a Section. Examination of the opening lines of a section (see Section 1, page T–5) reveals a pattern identical to that of the opening of the unit: the *title of the section*, the *pages of the child's textbook*, a *statement of the subconcept*, and an *interpretation for the teacher* that is related to the manner in which children will work toward understanding of the subconcept. Note that each subconcept is related to, and fills in, some aspect of the unit concept. Section subconcepts might well be considered as supporting concepts to the larger and more inclusive Unit Concept.

In the margin below the subconcept generally appears a listing of the **Processes emphasized** for the entire section. Not all processes will be used in every activity, nor will these necessarily be the only processes children will use. The teacher immediately sees, for example, that in Section 1 children may be encouraged to observe, investigate, hypothesize, theorize, analyze their observations, make predictions, and invent models. By these processes, and others in different sections, children approach conceptual understanding.

In each section, the child has experiences that enable him to take a specific step toward understanding some important concept. A section may be completed in one day in some instances; in others, several days will be needed. A lesson in this textbook does not imply completion of so many minutes of a classroom assignment, but gaining of an understanding of a concept, even though the child has never seen or heard the concept stated in specific terms.

Like good lessons in subjects other than science, the section has three main divisions:

- *the introduction*—in which a problem is raised and curiosity stimulated; that is, thought is linked to action;
- *the main body of the lesson*—in which the content is organized for concept development and then summarized;
- *the reinforcement or extension of the lesson*—in which a variety of activities is introduced for enrichment.

In the sections, or lessons, the children become aware of new relationships as they discover similarities among objects and events that previously may not have appeared to them to be related. Gradually, as they recognize and understand more clearly some of the more complicated patterns of relationships in the universe, for which they are ready on the fourth-grade level, the children build in depth their concepts in science. These concepts evolve in the child's mind as he takes each experience as a specific step toward understanding of increasingly mature concepts.

Introducing the Concept, the first part of each section, suggests an activity that raises questions or poses a problem. The activity may be a demonstration by the teacher, the making of a model, a class discussion, or a simple investigation. Occasionally some object or objects are desirable for examination. In Section 1 of Unit One (page T–6), this procedure is suggested, and the objects are listed as **Equipment and Materials** in the margin so that the teacher may see at a glance what may be useful to obtain for the opening of the lesson. In fact, wherever any activities are suggested that call for materials, the teacher will find a listing in the margin with a space in which to check their availability.

Once the section has been introduced, the teacher may further stimulate and guide the children's attention and curiosity by asking the pertinent question in bold-face type. To work toward uncovering the answers, the children turn naturally to their science textbooks and continue with the main part of the lesson.

Developing the Concept consists of several activities, usually from three to five, indicated by italic headings. These activities help the child to uncover evidence, see relationships, draw inferences, and in other ways move further toward understanding of the concept. The kind of evidence the children should discover is stated in the margin opposite the italic title. Equipment and materials are listed if necessary, except for the investigations in the child's textbook where the materials are listed in the investigation.

The heart of many of the lessons, or sections, is the *investigation*, always indicated in the child's textbook by the blue-tinted pages. If pitfalls in the investigation can be anticipated, or other learnings or questions may evolve from it, the teacher is alerted in the teaching suggestions. Otherwise, teachers follow the child's textbook and encourage design of the investigation and performance of it at the point indicated. If special equipment or alternate equipment for the investigation is supplied in the *Classroom Laboratory*, the availability of this equipment is indicated in the margin (see pages T–8 and T–10).

It is useful at this point to call attention to the illustrations, both in the text and in the investigation pages. The concepts of science rest upon observed evidence; that is, evidence observed and verified by someone. Unfortunately none of us can observe everything at first hand; in fact, we must rely upon indirect evidence for much that we learn. The evidence of pictures is perhaps the hardest to read. We tend to look at a picture before we know what it is that the picture can tell us—and then we don't come back to it. Or we read all about an object or event before we look at the illustration and often overlook something important that would help fix our understanding. To insure that the picture is "read" at the appropriate time, the picture is cued within the text by a symbol (square, circle, triangle, etc.) in color. Each cue means simply, "Now look at the picture—the one marked with a square." This is the right moment for inspection. There is no difficulty returning to the right point in the text, because the cue is there, clearly visible. Figure numbers and captions, used at higher levels of instruction, would tend, with younger children, to interrupt the reading or set the illustration apart from the context. This cuing of visualizations of evidence gives an improved degree of control over the learning situation.

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In the child's text, the outcome of an investigation can be seen in the photographs illustrating it, as a rule. The text of the investigation does not tell what the outcome will be; the picture must be inspected to see what happened. Thus, the importance of seeing, or observing, is stressed, even if, for some good reason, the investigation is not actually performed. When it is performed, the child has a guide by which to test his own results. However, we must also stress that the photographs show only how *one* trial came out. Scientists seldom accept the evidence of one trial. Variations in the children's results are to be expected. There may be good reasons for the variations, or perhaps the technique may be faulty. Children, then, should be cautioned not to accept one result and encouraged to make several trials to discover reasons for any discrepancies between their results and those pictured.

Extending the Concept, part of the main body of the lesson, but not a requirement of it, provides additional activities in which children may seek out further information in an area that interests them or apply a developed understanding in a new context. Some of these activities are suitable for slower-moving children who need reinforcement on a lower level; others offer a challenge to the more able.

Each section in the child's text closes with several types of activities, ranging from simple self-tests to investigations children may do on their own. Since teachers are busy persons, the answers to factual questions are given under **Reviewing the Concept** (see page T-7). The results of a pupil-planned activity are not indicated. He may achieve a different answer that satisfies the conditions of his activity or a more extended answer than might be given here. What the child uncovers and can defend on the basis of his own efforts is far more important than his arrival at an expected answer.

A good science lesson rarely ends at the close of a science period. One of the criteria used by teachers in evaluating the effectiveness of their teaching is the enthusiasm with which children continue to observe and investigate on their own. The lesson (section) then serves to point the way and to give meaning to children's continuing observations and investigations in their daily lives.

Closing the Unit. The last section of each unit (see page T-16), titled "The Main Concept," brings the central ideas of the subconcepts together in a summary that relates them to the Unit Concept and to the Conceptual Scheme. It is at this time that children should be encouraged to formulate their own statement of the Unit Concept. The exact words, as printed in the margin, are not important. Each child has his own understanding; any reasonable approximation of a statement of concept relationships should be accepted.

A New View. A comparison of the six conceptual schemes of *Concepts in Science* (pages F-14—15) shows that all these schemes are interrelated. In the fourth grade, children can begin to see these concept relationships and get a glimpse of the unity of the world in which they live. Hence, at four stages during the year's course, children take stock of conceptual relationships in sections titled "A New View." The first of these is related to sound and light, the second to matter, the third to living things, and the fourth to change. In each of the special sections, conceptual schemes are examined together, as will be evident from a reference to pages T-34 and T-35 at the close of the teaching suggestions for Unit Two. The remaining "New View" sections are at the close of Unit Four, Unit Six, and Unit Eight.

These "New View" sections encourage children to note and appreciate their growth in science. This growth is, of course, individual. But all the children come to some understanding of relationships between concepts. They can and do share an understanding of the world they have explored, each to his own capacity.

At the End of the Year's Work. Following the eight units and the final "New View" section is an end-of-book section titled "On Your Own: Probing with a Microscope" (see textbook page 285). Many children enjoy an extended activity; many are inveterate collectors; and still others are attracted by the opportunity to make discoveries on their own, quite independently of classroom experiences. The activities suggested in this section may be started with any child, with any group of children, or used to supplement the work of the text at any time. However this section may be used, it was prepared with the capacities of children to explore, collect, and classify clearly in mind.

For all the children, the text, carefully ordered in concepts, growing in complexity as each child grows in maturity, provides a series of firm foundation stones on which all may be guided to a firmer understanding of the higher ordering of concepts in *Concepts in Science 5*.

The Ultimate Goal. Each science lesson is designed to permit the child

1. to explore the material universe (through a "mix" of activity);
2. to seek orderly explanations of the objects and events explored (the explanation is an assertion we have called a *concept*);
3. to test his explanations (through a variety of activities).

The teacher's art is an individual one; the child's learning activity is an individual one. Nevertheless, the teacher's art is congruent to the scientist's when the child—in the teacher's hands—explores his world and, because of the teacher's great skill and understanding, is not crushed by the immensity of it.

Each lesson, in short, becomes an experience in search of meaning. A new concept of the way the world works becomes part of the child's equipment; it becomes part of his posture toward the world he lives in. He grows.

Useful Teacher References

Many books in science and science education offer splendid opportunities for additional study and investigations by pupils or for enrichment of teaching background. Harcourt, Brace & World publishes a number of textbooks for higher levels as well as several sourcebooks. Since they are referred to in this Teacher's Edition from time to time, the titles are cited below. In addition, a few other sourcebooks useful for reference and also cited in this Teacher's Edition are listed. Any of these are sufficient in conceptual depth and in richness of content to provide broad avenues of exploration for the most exacting teacher or the most inquisitive, imaginative, or creative child. The names and addresses of all the publishers whose titles are suggested here and in suggestions for individual units are on pages F–24—25.

The World of Living Things by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A general science textbook for junior high school, stressing biological science at an elementary level.

The World of Matter-Energy by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A general science textbook for junior high school, stressing earth and physical sciences at an elementary level.

Exploring the Sciences by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A complete, general science textbook for junior high school.

The Physical World, Second Edition, by Richard Brinckerhoff et al., Harcourt, Brace & World, 1963. A textbook in the physical sciences for ninth-grade pupils. Contains a special section of investigational activities for the more inquisitive and thoughtful pupil.

Teaching Elementary Science: A Sourcebook for Elementary Science by Elizabeth B. Hone et al., Harcourt, Brace & World, 1962. Descriptions of projects and experiments for pupils; techniques, field trips, demonstrations, and suggestions for planning instruction in biological and physical science are presented.

Teaching High School Science: A Sourcebook for the Biological Sciences by Evelyn Morholt et al., Harcourt, Brace & World, 1958. Similar in organization and planning to the elementary sourcebook cited above. Although designed for high school, it contains much useful material for the teacher and for pupils who develop special interests.

Teaching High School Science: A Sourcebook for the Physical Sciences by Alexander Joseph et al., Harcourt, Brace & World, 1961. Similar to the biological sciences sourcebook cited above, but for the physical sciences field.

Animal Worlds by Marston Bates, Random House, 1963. An authoritative study of animal adaptation and the science of ecology. Those characteristics that make each animal "world" unique are described and analyzed. Contains 245 illustrations, including 100 in full color. The reading level is definitely adult but not technical. Teachers will wish to share much of the information and many pictures with the children.

Foundations of Modern Biology Series, Prentice-Hall, 1961. A series of short, illustrated books on modern biology. Hard-to-locate descriptions of recent research and discoveries may be found in these books. The titles and authors are: *Man in Nature* by Marston Bates; *The Plant Kingdom* by Harold C. Bold; *Heredity* by David Bonner; *Animal Behavior* by Vincent Dethier and Eliot Stellar; *The Life of the Green Plant* by Arthur W. Galston; *Animal Diversity* by Earl D. Hanson; *Cellular Physiology and Biochemistry* by William D. McElroy; *Animal Physiology* by Knut Schmidt-Nielsen; *Animal Growth and Development* by Maurice Sussman; *The Cell* by Carl P. Swanson; and *Adaptation* by Wallace Bruce and A. M. Srb.

The Ideas of Biology by John Tyler Bonner, Harper & Row, 1962. Explains the larger themes of biology today. The chapters are "The Cell," "Evolution," "Genetics," "Development," "Simple to Complex," and "Man." Shows how each of the main themes of biology is related to the others. Presents an overview of the interrelationships of living things and of living things to their environment.

Matter by Ralph E. Lapp and the editors of *Life*, Time, Inc. From the *Life* Nature Library, Silver Burdett, 1963. Deals with the mysteries of matter that have stimulated the great intellectual explorations of our time. Each of the eight sections is accompanied by a picture essay. The narrative and pictures together constitute a survey of scientific advances in the subject. Teachers will want to bring much of the material to the attention of pupils.

Teaching Science Through Discovery by Arthur Carin and Robert B. Sund, Merrill, 1964. An intensely practical volume which can help teachers understand and practice a science program for the elementary school in accordance with the revolutionary nature of science education. The four section titles, "Shaping Science Education in the Elementary School," "Organizing and Planning for Teacher Science," "Enrichment Activities for Science Teaching-Learning," and "Discovery Lesson Plans and Other Activities for Teaching Science," barely suggest the rationale and framework for science instruction and learning which permeate all sections. Emphasis is on problem-solving and the "discovery approach," but specific, detailed, step-by-step teacher activities for organizing, planning, and teaching science are given. The appendix contains bibliographies of professional books, sources of science equipment and supplies and many other helpful lists.

ADDRESSES OF PUBLISHERS

Atheneum	Atheneum Publishers, 162 E. 38th St., New York, N.Y. 10016
Benefic Press	Benefic Press, 1900 N. Narragansett, Chicago, Ill. 60639
Childrens Press	Childrens Press, Inc., Jackson Blvd. and Racine Ave., Chicago, Ill. 60607
Creative Educational Society	Creative Educational Society, Inc., Mankato, Minn. 56001
Crowell	Thomas Y. Crowell Co., 201 Park Ave. So., New York, N.Y. 10003
Dodd, Mead	Dodd, Mead & Co., Inc., 432 Park Ave. So., New York, N.Y. 10016
Doubleday	Doubleday & Co., Inc., 277 Park Ave., New York, N.Y. 10017
Dutton	E. P. Dutton & Co., 201 Park Ave. So., New York, N.Y. 10003
F. A. Owen	F. A. Owen Publishing Co., Dansville, N.Y.
Franklin Watts	Franklin Watts, Inc., 575 Lexington Ave., New York, N.Y. 10022
Garrard Press	Garrard Publishing Co., 1607 N. Market St., Champaign, Ill. 61821
Harcourt, Brace & World	Harcourt, Brace & World, Inc., 757 Third Ave., New York, N.Y. 10017
Harper & Row	Harper & Row, Publishers, 49 E. 33rd St., New York, N.Y. 10016
Harvey House	Harvey House, Inc., Irvington-on-Hudson, N.Y. 10533
Henry Z. Walck	Henry Z. Walck, Inc., 19 Union Sq. W., New York, N.Y. 10003
John Day	The John Day Co., Inc., 200 Madison Ave., New York, N.Y. 10016
Knopf	Alfred A. Knopf, Inc., 501 Madison Ave., New York, N.Y. 10022
McGraw-Hill	McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York, N.Y. 10036

Melmont	Melmont Publishers, Inc., Jackson Blvd. and Racine Ave., Chicago, Ill. 60607
Merrill	Charles E. Merrill Books, Inc., 1300 Alum Creek Dr., Columbus, Ohio 43216
Morrow	William Morrow & Co., Inc., 425 Park Ave. So., New York, N.Y. 10016
Prentice-Hall	Prentice-Hall, Inc., Englewood Cliffs, N.J. 07631
Random House	Random House, Inc., 457 Madison Ave., New York, N.Y. 10022
Scribner's	Charles Scribner's Sons, 595 Fifth Ave., New York, N.Y. 10017
Singer	L. W. Singer, Inc., 249 W. Erie Blvd., Syracuse, N.Y. 13202
Time, Inc.	Time, Inc., Book Division, Time-Life Bldg., Rockefeller Center, New York, N.Y. 10020
Whittlesey House	See McGraw-Hill
World Publishing	World Publishing Co., 2231 W. 110th St., Cleveland, Ohio 44102

ADDRESSES OF AUDIOVISUAL SUPPLIERS

The teaching suggestions for each unit of this Teacher's Edition list a number of films and filmstrips for classroom showing. Orders or further requests for information should be addressed to the following distributors or suppliers whose names are given in abbreviated form at the left.

Cenco	Cenco Educational Films, 1700 Irving Park Rd., Chicago, Ill. 60613
E. B. F.	Encyclopaedia Britannica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill. 60613
F. A.	Film Associates of California, 10511 Santa Monica Blvd., Los Angeles, Calif. 90025
I. F. B.	International Film Bureau, Inc., 57 E. Jackson Blvd., Chicago, Ill. 60604
Jam Handy	Jam Handy Organization, 2821 E. Grand Ave., Detroit, Mich. 48211
L. F. S.	Long Filmslide Service, 7505 Fairmount Ave., El Cerrito 8, Calif.
McGraw-Hill	McGraw-Hill Publishing Co., Text Film Dept., 330 W. 42nd St., New York, N.Y. 10036
S. V. E.	Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill. 60614

Answer Key to TEACHING TESTS

Unit One

1. a
2. b
3. a
4. b
5. b
6. low pitch
7. vibrations
8. high pitch
9. echoes
10. vocal cords
11. b
12. a
13. c
14. c
15. a

Unit Two

1. b
2. a
3. a
4. b
5. b
6. black paper
7. lens
8. television screen
9. mirror
10. polarized plastic
11. c
12. a
13. b
14. a
15. c

Unit Three

1. a
2. f
3. b
4. a
5. a
6. reservoir
7. water table
8. chlorine
9. watershed
10. settling tank
11. a
12. c
13. c
14. b
15. b

Unit Four

1. b
2. b
3. a
4. a
5. b
6. air
7. iron
8. iron oxide
9. oxygen
10. water
11. c
12. a
13. a
14. c
15. b

Unit Five

1. b
2. a
3. b
4. b
5. a
6. glucose
7. starch
8. protein
9. sucrose
10. fat
11. a
12. c
13. b
14. a
15. b

Unit Six

1. b
2. a
3. b
4. a
5. b
6. sperm
7. yolk sac
8. protozoans
9. smolt
10. fish ladders
11. c
12. a
13. b
14. c
15. b

Unit Seven

1. a
2. a
3. b
4. b
5. b
6. river
7. gully
8. sediment
9. mouth of river
10. mountain
11. b
12. a
13. c
14. a
15. c

Unit Eight

1. a
2. d
3. c
4. a
5. b
6. meteor
7. Sun
8. planet
9. Moon
10. meteorite
11. c
12. b
13. b
14. c
15. a

4

Concepts in SCIENCE

PAUL F. BRANDWEIN
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ILLUSTRATOR

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CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

Unit One

THE BOUNCE OF SOUND

(Text pages 2–27)

Using some of the processes and knowledge of science, children begin to explore the nature of sound and begin to obtain a concept of sound as a form of energy.

UNIT CONCEPT

A loss or gain of energy affects molecular motion.

A VIEW OF THE UNIT

A Preview of the Concepts

The tick of a clock in a quiet room, the purr of a kitten, the clang of a bell, the roar of a jet engine, are very different sounds, produced by very different things. Yet different as they are, these sounds are basically alike. All sounds, of whatever kind, have hidden likenesses. Scientists have managed to uncover these hidden likenesses. What are they, and how have scientists been able to find them? Once they are found, of what use are they? With this unit children may begin, or continue, to find answers to these questions and to enlarge their understanding of the nature of science and its concepts.

Sound as Vibration, a To-and-Fro Motion

How are sounds made? Children come to understand that, no matter how different sounds may be, the sound is made by the to-and-fro motion of some object: by a vibration. (This is not to say that all vibrations produce sounds.) A simple investigation provides experiences that illustrate the concept: where there is sound, there is vibration. "Many investigations and experiments, by many scientists, have shown it is so" (page 6). It is pointed out that one experience is not proof!

One thing which makes sounds different is that they may be high or low. What makes one sound high, like the song of a bird, and another low, like the rumble of an automobile engine? An investigation using a comb and a bit of cardboard reveals that by changing the rate at which the cardboard vibrates, the pitch of the sound made by the vibrating cardboard is changed. The faster the vibrations, the higher the pitch, and the lower the vibrations, the lower the pitch. Thus the children find that one discovery, about vibrations and sound, leads to another, about vibrations and pitch. Some of the ways in which the rate of vibrations can be changed are pointed out.

Sound is caused by vibrations, then. But this raises a puzzling problem. We hear with our ears. How do the vibrations of an object travel to our ears? An investigation with a length of clothesline shows that a vibration at one end of the rope can travel the length of the rope, as a wave. The children observe that vibrations in water make waves that carry the vibration along the surface. Even though they cannot be seen, vibrations in air produce waves that travel through the air to our ears.

Sound as Molecules in Motion

Sound waves can travel through air. Scientists have a theory that air (like other substances) is made up of molecules. Children find that by using this theory they can form an idea of *how* sound waves can travel through air by the bumping of molecules. They find, too, that this theory helps to explain why sound travels better through a solid substance like wood or metal than through a gas like air, as an investigation shows.

Does what the children have learned about sound help to explain that curious phenomenon, an echo? The bouncing of molecules suggests that sound waves may bounce back from a hard surface and return to their starting point. This in turn leads to the realization that sound must travel through air at some definite speed, since an echo takes time to return. While sound waves can bounce off some materials, they can be absorbed by some others.

Thus some ideas about the nature of sound are arrived at. These ideas or concepts are arrived at, however, with the help of some of the processes and knowledge of science. Underlying these concepts about sound is the even broader concept of the molecular theory, of molecules in motion. The theory will be found useful again, in other areas. And the way is being prepared by which these concepts about sound will be related to the powerful concept of energy, in the following unit.

SUPPLEMENTARY AIDS

All the films below are in color unless otherwise noted. In order to have them available at the time you wish to show them, it is advisable to order or reserve them on loan from the supplier well in advance. The names and addresses of distributors of films and filmstrips, listed here by abbreviation, are given on page F-25. All films and filmstrips, unless otherwise noted, are considered to be of approximately the right level of content and difficulty for the grade.

Films

Sound and How It Travels (11 min.), E.B.F. Simple investigations explain basic concepts: what causes sound; why we are able to hear sounds; how sound travels; the factors that determine pitch.

Vibrations (14 min.), E.B.F. Animated diagrams show the chain of actions taking place as the vibrating arms of a tuning fork strike against air particles which in turn strike against our ears. Stop-motion photography shows that two things are needed to make a vibration: a force that pulls the vibrating object, and the tendency for a moving object to keep moving.

Sounds Around Us (11 min., sound), Cenco, 1964. Explains how sounds are produced by a vibrating object; how different vibrations result in differences of pitch; how sound waves travel; and what causes an echo.

Filmstrips

Sound (49 frames), E.B.F., 1954. Animated drawings explain how sound is made; the speed of sound waves; how the speed of vibration determines pitch; what causes reflection of sound waves; how man uses his knowledge of sound for his own use.

Exploring Sound (43 frames), McGraw-Hill, 1957. Simple investigations explain what causes sound; what causes a change in pitch; how regular or irregular vibrations affect sounds; what causes an echo; how sound waves travel.

Finding Out About Sound (37 frames), S.V.E. Explains what causes vibrations; how they produce sound waves; how these waves travel through air, water, and along a wire; what causes an echo. A diagram of the ears shows how we hear sound.

The Nature of Sound (40 frames), Jam Handy, 1959. Simple investigations explain how vibration causes sound; how bumping molecules produce sound waves; how it is possible to control both the volume and the pitch of sound.

How Sound Travels (40 frames), Jam Handy. Investigations show how sound travels; that sound waves travel more slowly than light waves; that sound waves bounce or are reflected. Explains how we hear sounds.

Science Reading Table

Books on a reading table in one part of the room for free reading and investigation stimulates an interest in elementary science. Many titles are available and more are continually being published. The ones below have been found useful for this unit; those starred (*) are especially recommended as having suitable and readable sections for enlarging upon the content and concepts of this unit. Following each title appears a rating of the reading level in relation to that of the pupil's textbook. The full names and addresses of the publishers are on page F-24.

The First Book of Sound, by David C. Knight, Franklin Watts, 1960. A guide to the basic facts of sound. Relates basic principles of sound to practical applications. Includes discussion of ultrasonics and faster-than-sound aircraft and missiles. (Average)

Junior Science Book of Sound, by Dorothy S. Anderson, Garrard Press, 1962. An introductory study of sound. Descriptions of the production, transmission, and hearing of sound are related to sounds made by animals, musical instruments, and the human voice. Simple investigations help the reader to develop an understanding of the basic characteristics of sound. (Easy)

**The Magic of Sound*, by Larry Kettlekamp, Morrow, 1956. Many examples and investigations help the reader to understand the basic ideas of vibration. Emphasizes basic characteristics of sound. (Advanced)

Sounds All Around, by Tillie S. Pine and Joseph Levine, Whittlesey House, McGraw-Hill, 1959. Scientific principles of sound are simply described and illustrated. Activities and information are presented to increase the reader's interest and awareness of sound. (Easy)

Sounds You Cannot Hear, by Eric Windle, Prentice-Hall, 1963. Explores the world of ultrasonics. Sound waves are described and applied to the study of ultrasonics. Includes description of how bats fly at night and how sonar works. (Advanced)

°*The True Book of Sounds We Hear,* by Illa Podendorf, Childrens Press, 1961. Calls attention of the reader to sounds about him. Describes how we hear, contrasts pleasant and unpleasant sounds, and shows how sounds may convey different meanings. (Easy)

What Is Sound, by Gabriel H. Reuben, Benefic Press, 1960. Describes the basic characteristics of sound. Provides an overview of the subject for selection of topics for further exploration and study. Contains brief sections on the voice, the ear, and man's use of sound. (Average)

°*Wonders of Sound,* by Rocco Feravolo, Dodd, Mead, 1962. Includes description of what sound waves are; how they travel; what makes high and low sounds; about tuning forks, loudspeakers, soundproofing, echoes, and sound recording. Easy investigations for average pupils to do are clearly explained and illustrated. (Advanced)

Classroom Laboratory—Assembling and Organizing Materials

In addition to planning in advance for films, filmstrips, and books for yourself and the science reading table, it is well to check beforehand on materials you have available for demonstrations and investigations. Throughout this Teacher's Edition, marginal notations are given under the heading "Equipment and Materials" wherever an investigation is suggested to supplement the work of the pupil's textbook. These materials are usually readily available in the classroom or easily obtainable by pupils from local or home resources.

The child's textbook includes a number of investigations, indicated by a blue tint on the pages on which they occur. The equipment needed is listed at the beginning of the investigation. The number of items you will need to have on hand depends on whether you plan to use the investigation as a demonstration or to have children work individually or in groups. For efficient investigating, materials should be gathered in advance or ordered, if necessary, from the school supply room.

As more fully described on pages F-17–18, a set of laboratory equipment and materials, *Classroom Laboratory 4,* to accompany *Concepts in Science 4,* is available from the publisher. The materials are conveniently packaged so that six groups of pupils, as a rule, may work on an investigation at one time. An exception is that a few items, such as alcohol lamps, are provided singly. Most of the investigations in *Concepts in Science 4* can be performed by using these materials which are the same or similar to those suggested on the investigation pages. Notations are given in the margin of this Teacher's Edition for many investigations. If you have *Classroom Laboratory 4,* it is useful to refer to Part II of the Teacher's Manual, which is included in it. You will find suggestions for carrying out the textbook investigations and other investigations that extend the concepts.

▶ INTRODUCING THE UNIT

The illustration that opens each unit has been selected to provide one way of entering the unit. If this illustration is examined by the class, and discussed, the topic of the unit will certainly be brought up. Turn to the unit opening illustration on page 2, showing a boy playing cymbals. Questions like these will surely start the children talking about sound: What does this picture make you think of? What does it show happening? Does the picture make you think of a sound? How would you describe this sound? Can you think of an entirely different sound? Then, when the discussion has gone as far as you wish, read what the unit introduction (opposite the illustration) says about different sounds.

Section 1: MAKING A SOUND

Children observe that where there is a sound, something is vibrating.

(Text pages 4–7)

SUBCONCEPT

Sound is caused by a vibrating object.

Processes emphasized

- Investigation (with design of an experiment)
- Observation
- Analysis of observation
- Hypothesizing
- Theorizing
- Prediction
- Invention of models

Introducing the Concept

Print on the chalkboard HEARING TEST. When the room is quiet, ask: "What do you hear?" Make a list of the sounds the children name. (Notice how many commonplace sounds are going on that we pay no attention to!) The list will certainly contain many different sounds, and you can ask, to establish this point, if the sounds listed are alike or different. How are they different? Words like soft, loud, high, low, harsh, smooth, may be used to describe the sounds and to make the point that sounds do differ.

In what way could all sounds possibly be alike?

You may want to get some reactions from your pupils to this question. Then they can be asked to read text page 4, and to try the investigation on the opposite page, to which this section leads.

Children find that vibrating objects make sounds, and that the movement is a to-and-fro kind.

Equipment and Materials

See text page 5; also the Teacher's Manual for *Classroom Laboratory 4.*

Developing the Concept

The investigation—making a sound. It's a safe prediction that some youngsters will not be content with reading the investigation; they will want to try it. They may be astonished to find that if the pie tin or saucer (or whatever the rubber band is stretched on) is pressed against the ear, the rubber band makes a very musical sound. Of course they will find that tightening or loosening the band can change its pitch (and some children may want to demonstrate that rubber bands are guided missiles!). Whatever else they find, they will find that when there is a sound from the rubber band, the band can be seen moving; and if the movement is stopped, the sound stops. The same is true of the ruler: when it moves, it sounds; and when the movement stops, the sound stops. Whatever else they observe, they should observe that the movement that makes the sound is of a certain kind. It is a back-and-forth, to-and-fro movement. Thus the concept that where there is a sound something is moving is introduced.

The additional investigation poses questions which have to be investigated to be answered, although the answers may be guessed at. A tiny bit of folded paper hung on a piano or guitar string will be shaken off when the string sounds, because of the movement of the strings.

Can the children answer the questions in the investigation out of their experiences with the materials? Then it may be time to read the section headed **Sound and Movement** (text pages 4 and 6).

Where there is sound, there is movement.

Sound and movement. The text explains the outcome of the investigation, and the concept that where there is sound there is movement is extended beyond rubber bands and rulers. More evidence for the concept is referred to. You may want to bring a bell or a drum into class, and let children touch it as it sounds.

Equipment and Materials

. . . long knife
. . . spatula
. . . hacksaw blade
. . . C-clamp

Instead of a ruler, try twanging the blade of a long knife, a spatula, or a hacksaw blade. A C-clamp will hold the blade to a tabletop. By extending the blade farther, its action will be slowed down and seen as a to-and-fro movement.

A vibration is a to-and-fro movement.

To and fro. Now the word *vibration* is introduced as a term to describe the kind of movement that sounding objects make. What examples of to-and-fro vibrating movement are there around us? (A clock pendulum, a playground swing.) Sound means that vibration is taking place. This does not mean that where there is vibration, there is sound, of course. You can vibrate your hand, as the text notes, without hearing a sound. However, where there is sound, there is vibration, even though it may not be visible.

Equipment and Materials

. . . grain of cereal or small cork
. . . thread
. . . tuning fork
. . . rubber bands

Suspend a grain of puffed cereal or a small light cork by a thread. Strike a prong of a tuning fork against a rubber heel (thus the fork won't be damaged). The sound of the vibrating prongs is heard, but their movement is so small and quick that it can't be seen. Lightly touch the tip of one prong to the dangling object. Why does the cereal or cork jerk? (The prongs are vibrating.) If the tuning fork is struck harder, what happens to the sound? What happens to the cereal or cork when touched?

Let a pupil make and set up the chain of rubber bands, described in the text (page 6). It will show, in slow motion, how the strings of an instrument like a violin or guitar may vibrate when making a sound.

Radio and television sets make sound. Do they vibrate? Touch the cabinet. What do you feel as you hear the sound? If you change the volume, do you notice a change in what you feel?

Do you know how to make a grass blade "sing"? Someone in your class may know, if you don't. Can you feel the blade of grass vibrate as you blow on it? The vibrating blade acts like the vibrating reed in a clarinet, which might be demonstrated with the help of the school music teacher. What other instruments make sound with vibrating reeds? Your children may find it interesting to explore vibration in different musical instruments, with the cooperation of the music teacher.

Extending the Concept

Two kinds of vibrations. A swing, a rocking chair, or a tuning fork, once it starts vibrating, vibrates naturally and freely at a certain rate. Such vibrations are called natural vibrations or free vibrations. Can you think of other examples of natural or free vibration? (A guitar string, a drumhead, a gong, the tines of a fork, a stretched rubber band.)

Natural or free vibration is one kind of vibration. However, you can make a rocking chair or a swing vibrate at a different rate from its natural one, by pushing and pulling without letting go. This kind of vibration is called forced vibration. Hold an empty pie tin (used in the investigation) close to your ear, and tap its center with a fingernail. The pie tin will probably give off a musical sound. It is vibrating freely or naturally. By stretching a rubber band around it, and plucking the rubber band, you can force the tin to vibrate at a different rate from its natural one. Can you think of other examples of forced vibration? What is happening when a vibrating tuning fork is pressed against a door or a tabletop?

Reviewing the Concept

(Text page 7)

Before You Go On. 1. a 2. b 3. a

Using What You Know. The strings of a tennis racket are set into vibration when they strike the ball. Pluck the strings of a racket with a finger and see!

Section 2: HIGH AND LOW

(Text pages 8–11)

SUBCONCEPT

The pitch of a sound depends on the rate of the vibrations.

Children find how the pitch of a sound may be changed.

Introducing the Concept

Equipment and Materials

. . . soda straw
. . . scissors

You can demonstrate a changing pitch—and raise the question of what makes it change—in a rather dramatic way with a straw and scissors.

Flatten one end of a straw for about ¾ of an inch. Trim the flattened end to a point, using scissors to do the trimming. Moisten the point lightly, then put it into your mouth far enough so that your lips touch the unflattened part of the straw. Blow through the straw—you may have to blow hard—and a somewhat musical sound will be produced as the pointed flaps of the straw (inside your mouth) vibrate. Now, as the sound is made, snip a bit off the end of the straw with the scissors. The pitch of the straw will rise abruptly as the length of the straw is shortened.

It may be well to practice this before class begins, so that you can do it with composure. But it will provoke questions.

How is the sound made? (Vibration of the pointed flaps by your windstream.) **What is heard happening as the bits are snipped off?** (The tone goes higher and higher.) **Why does this happen?**

Without evaluating the proffered answers to this one, you are now ready to turn to the opening of Section 2 and the investigation (text page 9).

Of course your pupils will want to try the sounding straw for themselves. Watch out that no noses are snipped in the excitement. It may be safest to have one youngster blow while another snips with care.

Equipment and Materials

- . . . rubber band
- . . . pie tin
- . . . empty bottle

(See text page 9; also the Teacher's Manual for *Classroom Laboratory 4.*)

Another demonstration of change in pitch can be done with a rubber band around a pie tin, loosened and tightened. Or blow across the top of an empty bottle to make it sing; then put an inch or two of water in it so that the pitch is higher. Of course, the first answer to the question, "What makes the sound higher?" is that the straw has been shortened, or the rubber band tightened, or the bottle partly filled with water. The question these answers lead to is the important one.

How do changes in objects make the sound go higher or increase in pitch?

(The answer is that the vibrations have been speeded up. To lower the pitch, the vibrations are slowed down.)

Developing the Concept

Pupils discover that changing the rate of vibration changes the pitch.

The investigation—high and low pitch. By drawing a piece of cardboard across the teeth of a comb, the cardboard is made to vibrate. By drawing it faster or slower, it is made to vibrate faster or slower—and the children can observe that the faster the vibrations, the higher the pitch; slower vibrations mean lower pitch. The steadier the motion of the cardboard across the comb, the steadier the pitch will be—and the easier to recognize.

Processes emphasized

Investigation (with design of an experiment)
Observation
Analysis of observations
Hypothesizing
Theorizing
Reporting
Consulting
Invention of models

Equipment and Materials

- . . . saw
- . . . piece of cardboard
- . . . guitar or other stringed instrument
- . . . a few feet of string or twine

Does drawing the cardboard along the comb remind you of something else like it? What about drawing a stick along a fence? It starts the stick vibrating, of course.

Can you think of other ways in which you can make something vibrate at different rates? A piece of cardboard (or other material) drawn lightly along the teeth of a saw (which are sharp!) will make a pitched note.

You may want to return to the rubber band and pie tin to observe that when the band is loose and its pitch is low, it is vibrating more slowly than when its pitch is higher. The low string on a guitar can be loosened until the vibrations are slow enough to be visible, then tightened to increase the rate of vibration—and the pitch rises. This is even more striking on a double-bass's low string—if one is available. Or an ordinary piece of string a few feet long may be tied to something firm (as a door knob) and tightened or loosened to change its rate of vibration—and its pitch.

After the investigation has been explored, turn to the section headed **Fast and Slow** (text page 8). This section confirms the findings and observations in the investigation, that the pitch of the sound made depends on the rate (or speed) of the vibrations making the sound. The concept is extended to all pitched sounds. The answer to the question posed at the beginning of the section is given. Have the children hum a high note and a low note while holding their hands on their throats (as they did to begin with). Can they now answer the question: What are their vocal cords doing to make the note high or low? (The vocal cords are vibrating faster or slower.)

Changing the pitch. How many ways have been used to change the pitch of sounds in the class? How many ways of changing pitch do stringed musical instruments use? Tightening or loosening a string makes its rate of vibration change. So does making the string heavier or lighter. Changing the length of the string is another way that is not mentioned in the text.

Rate of vibration can be changed in different ways.

Extending the Concept

Music and noise. How does a musical sound differ from a noise? It is due to a difference in the kind of vibration. A musical sound is produced by regular vibrations. A noise is produced by irregular, uneven vibrations. A model siren may be used to show this. Punch a series of evenly spaced holes around the inner edge of a foil pie tin. (A pencil box protractor will be useful.) Then punch another, outer, row of unevenly spaced holes. Through a hole in the center of the pie tin, fasten the tin to a drill (hand-powered), so that when the handle of the drill is turned, the tin revolves (rotates). Use a C-clamp to hold the drill horizontally on the edge of a table. Rotate the tin and direct a stream of air through a straw or rubber tubing at the moving holes. The even row will produce a musical pitch, because the holes set up even vibrations in the air stream. The uneven holes will make a noise because the vibrations they produce are not regular.

Equipment and Materials

. . . foil pie tin
. . . protractor
. . . hand-powered drill
. . . C-clamp
. . . straw or tubing

Reviewing the Concept

(Text page 11)

Before You Go On. 1. a 2. b 3. b

Using What You Know. A bass viol produces very slow vibrations of the heavy strings so that they make a low-pitched sound. A violin produces very fast vibrations (of its tightest and lightest string) to make high-pitched sounds.

Section 3: PUSHING AND PULLING MOLECULES

(Text pages 12–16)

SUBCONCEPT
Sound travels in waves, by molecular motion.

Children come to understand how sound travels through matter.

Introducing the Concept

How does sound reach your ear? We are so used to sound reaching our ears that we rarely stop to think *how* sound gets from its source to our ears. Can we help children realize that there is something to investigate here? You might try this: Ask the class to close their eyes. Then sound

Equipment and Materials
. . . bell or tuning fork

a musical note from a bell, a tuning fork, or some such sound-maker, which you have kept out of sight. What is sounding? (Children will recognize it, of course.) What is it doing while sounding? (Vibrating.) And now the big question:

If it is vibrating *here*—and your ears are *there*—how do the vibrations get from here to there?

When there has been enough discussion (which need not be evaluated), you may want to suggest that the text has an investigation which may offer some evidence. Read the paragraphs under **Pushing and Pulling Molecules** and try the investigation, on page 13.

Developing the Concept

Children, by investigation, see that waves transmit energy in all directions.

Processes emphasized
Investigation (with design of an experiment)
Observation
Analysis of observations
Hypothesizing
Theorizing
Prediction
Reporting
Library research

Equipment and Materials
. . . cork or foil pan
. . . dishpan or sink
(See text page 13; also the Teacher's Manual for *Concepts in Science 4*.)

The investigation—waves. With a little practice, you'll find that a wave in the form of a half loop of the rope can be made to travel the length of the rope. A brisk and vigorous movement of the hand will send a wave down the rope. You may find (depending on the rope) that letting the rope lie on the floor, instead of its hanging above the floor, will work best. What is put in at one end? (Energy.) What travels along the rope to the other end? (Energy.) By sending waves along the rope, then, we are able to send energy from one end to the other. Can the energy do some work at the far end of the rope? Put a piece of paper over the rope and let a wave fling the paper into the air. A wave in the rope carries energy, the energy of vibrations.

Set a cork or a "boat" made out of foil paper afloat in the middle of a dishpan or the classroom sink. Can you make the boat move without touching it—and not by blowing? Waves made at the edge of the water with a finger or a stick vibrating in the water will travel to the boat and make it move up and down. The water waves carry energy from the stick (or finger) to the boat; the energy makes the boat move. Waves carry energy, from vibrations.

Do the water waves travel any particular way? Wiggle a finger in calm water in the center of the pan, having taken out the boat. How do the waves spread? They move out from the center in concentric rings, in every direction.

Does this suggest anything about how sound vibrations might travel from the vibrating object to the ear? When the surmises have gone on long enough, it may be time to read the section headed **Waves** (text pages 12 and 14).

Equipment and Materials
. . . small bell
. . . string
. . . Pyrex flask
. . . heat

Waves. Tack a small bell suspended on a string to the bottom of a stopper or cork for a Pyrex flask or coffeepot. Put the stopper in the flask, and shake the flask. Notice how loud the sound is. Remove the stopper and bell, and put about an inch of water in the flask. Boil vigorously, for a minute or two. The water vapor will drive air out of the flask. Remove the flask from the heat and insert bell and stopper. As the flask cools, the water vapor in it will condense and form a partial vacuum; the flask will not have as much air in it as it had at first. Does the bell sound fainter now? Why? Since waves of sound travel through air, less air means less sound. This corresponds to the vacuum pump demonstration described in the text.

Bouncing molecules. Sound waves travel through air; but how? By the molecules in the air pushing each other. To suggest how vibrations are passed along from molecule to molecule, have children stand in a long single line, about two feet apart, and face the head of the line. On signal the last child in the line steps forward just far enough to nudge the child ahead, then steps back into position. The nudged child then steps forward to nudge the one ahead, and steps back. Where did the sound come from? (The end of the line.) What does each child stand for? (A molecule in the air.)

Sound travels by the motion of molecules.

Extending the Concept

Sound waves and the ear. What happens when sound waves reach the ear, having traveled through the air? Make a model eardrum by stretching waxed paper taut between a pair of embroidery hoops. If you speak to the waxed paper on the hoops, can the vibrations of the paper be felt? Lay a few light grains of puffed cereal on the paper hoop. Does sound make them move? The paper picks up sound vibrations from the air. Compare this to the eardrum. If the waxed paper drum is punctured or broken, does it pick up vibrations as before? Can the children explain the advice, "Never put anything smaller than your elbow in your ear?" Your school nurse or doctor may welcome the opportunity to visit with you about this. They may bring a model of the ear and point out where the eardrum is located.

Equipment and Materials

. . . waxed paper
. . . embroidery hoops
. . . puffed cereal

Reviewing the Concept

(*Text page 16*)

Before You Go On. 1. b 2. a 3. a

Using What You Know. Since there is no air on the Moon, the vibrations made by rapping cannot travel from one astronaut to the other. The astronaut in front will not hear the astronaut in back.

Section 4: SOUND AND MOLECULES

(*Text pages 17–20*)

SUBCONCEPT

The molecular theory explains the behavior of sound in a solid and a gas.

Equipment and Materials

. . . two saucers
. . . perfume
. . . water

Children find that sound travels better through some solids than in air.

Introducing the Concept

Put a few drops of perfume on a saucer. How long does it take children to detect the perfume in different parts of the room? How does the perfume spread through the room? As the perfume in the dish evaporates, tiny particles of the perfume take to the air and are carried

Processes emphasized

- Observation
- Analysis of observations
- Hypothesizing
- Design of investigation (with experiment)
- Theorizing
- Model-making
- Analysis of ways of the scientist
- Library research

into all parts of the room. These tiny particles of perfume are molecules.

Put a little water in a saucer. What will happen to the water if it is left there? It will disappear, gradually. Molecules of water take to the air (like the perfume); they leave the liquid and become a gas (water vapor). (Check on the water later; is it disappearing?)

What idea accounts for the behavior of the water and perfume? (The action of molecules.)

The idea of molecules can explain some things that happen to sound, too. Read the section as far as **The Theory Helps** and encourage pupils to design the investigation on text page 19.

Developing the Concept

Matter is molecular in nature.

Molecules in matter. All the different objects seen in the classroom are the same in what one respect? All are made up of molecules. All are made of molecules in one of three forms. Can you, before a friend counts ten, tell whether the object he points to is solid, liquid, or gas? This might make a class game, with choosing sides and keeping score.

Before trying the investigation, you may want to ask the class to predict what will happen if a sound is sent through a solid, instead of through a gas such as air. Invite them to predict after they have looked at the diagrams of molecules in a solid and molecules in a gas, on pages 17 and 18. Can sound travel through a solid, do they think? Through which should sound travel better, a solid or a gas? The investigation will furnish evidence for the correct answers.

Children investigate the behavior of sound in two states of matter.

Equipment and Materials

. . . waxed cord
. . . thin wire
. . . tin cans

(See text page 19; also the Teacher's Manual for *Classroom Laboratory 4.*)

The investigation—sound in a gas and a solid. Sturdy paper or plastic cups will allow the use of a longer string and make a still more effective demonstration. Why must the string be kept taut, if sound is to travel along it? It will be found that sound travels better through the string than through air, and better through wood than air. Now the predictions can be checked! But you may want to encourage further explorations in transmitting sound. Try a different kind of cord; waxed cord; thin wire. Try tin cans instead of paper cups. Why is sound transmitted better when the cup or can is held lightly? Is the transmission affected if someone touches the taut string? Why? Does it make any difference if a button is used instead of a matchstick to fasten the string to the cup or can? If a second string is tied on, making the shape of a Y, with a cup attached, can you hear on this "party line"? Why can't the string telephone be used around a corner? No doubt the children will have some ideas of their own to try, as well.

The molecular theory explains why sound travels better in a solid than in a gas.

The theory helps. Sound does travel better through a solid like wood (or even string) than through air, and the theory that things are made of molecules helps us to explain why this is so: the molecules in a solid are closer together than in a gas, and bump better.

This may be a good time to reform the line of children who modeled the passing along of a sound wave by a line of "molecules," and see what happens if the "molecules" stand closer together. A nudge can be passed along the line now with less effort and motion than when the children were farther apart.

Is it a *fact* that sound is carried through a substance by molecules bumping each other? No, we cannot say so, for we have never seen molecules behaving so—because the molecules cannot be seen. But we imagine that molecules behave so, on the basis of a great deal of indirect evidence. So we call this idea of how molecules behave a theory rather than a fact.

Extending the Concept

Equipment and Materials
. . . paper bag
. . . apple

Theory and hypothesis. What is the difference between a theory and a hypothesis, in science? Both are ideas that try to explain things, but a theory has a good deal of accepted evidence to support it; a hypothesis has only a little. Put an object—an apple, say—in a paper bag too large for it, and close the bag tightly. Now show the bag to the children. Can they guess what is in the bag? You may let the bag hit the table, to show that there is something solid inside. The guesses, on the little evidence available, are hypotheses of a sort. For the scientist, a hypothesis is to be tested. Let them test their hypotheses by feeling the bag, by weighing it, by smelling it—by whatever they can suggest, except opening it to see! Now as they accumulate evidence of different kinds—and they agree (as scientists must) among themselves as to what the evidence means—the hypothesis becomes a theory: a theory that what is in the bag behaves as if it were an apple.

It is up to you whether you let them see what is in the bag or not!

Reviewing the Concept

(*Text page 20*)

Before You Go On. 1. b 2. b 3. a

Using What You Know. 1. Sound of hoofbeats travels better through the solid ground than through the air. 2. Under water; the molecules in water, a liquid, are closer together than the molecules in air, a mixture of gases.

Section 5: WHEN SOUND RETURNS

(*Text pages 21–25*)

SUBCONCEPT
An echo is caused by the bounce of sound.

Children find that sound waves can bounce back from a solid surface.

Introducing the Concept

Tie one end of 12 feet or so of light rope or sash cord to something solid—a doorknob or the leg of a desk, perhaps. Ask a child to send a wave along the rope, as was done in the investigation in Section 3, page 13. This time, however, the question is, what happens when a wave

Equipment and Materials

. . . 12 feet of light rope
. . . Slinky coil
. . . dishpan

Equipment and Materials

. . . three different rubber balls
. . . colored chalk
. . . string

Processes emphasized

Development of model
Analysis of model
Discussion
Investigation (with analysis of devices)
Hypothesizing
Theorizing

reaches the tied end of the rope? The children will observe (if they have not done so already) that when a wave with plenty of energy reaches the anchored end, it starts back. The wave bounces back from the solid surface, in other words. A wave in a rope can bounce back.

The same thing can be shown to happen to waves in a Slinky. Pinch a few of the coils together and let them go, quickly. The wave that travels the length of the extended Slinky will (if you have given it enough energy) bounce back from the end of the coil.

The same sort of thing can be shown with water in a dishpan. When the water is calm, dip a finger quickly into it, and out. What happens to the water wave when it reaches the side of the container? If you look carefully, you may see it hit the side and start back. Waves in water can bounce from a surface. Investigate the question through discussion:

Can waves in solids, liquids, and gases bounce?

Is a rope a solid, liquid, or gas? The waves in the rope or Slinky show that waves in a solid can bounce. Is water a solid, liquid, or gas? Waves traveling in a liquid can bounce. What do you think about waves in a gas—sound waves, for instance? Can they bounce? After as much discussion of this question by the children as you think useful, turn to the beginning of Section 5, and read as far as **How Fast Is Sound?**

Developing the Concept

Sound that hits a wall can bounce back.

Why sound returns. Have any of the children visited places where there were echoes? How long did the echo take to come back? What did the sound bounce back from? Was there more than one echo? How could you explain this? (More than one surface to bounce off.)

You may want to point out in the series of diagrams on pages 21 and 22 how the sound waves hit the wall one after another, and so *return in the same order* they go. Thus we hear the sounds that are echoed in the same order in which we made them—not reversed. If you roll three different-colored rubber balls against a wall in a certain order, they will bounce back in the same order.

Can you make a picture of an echo? A point at one side of the chalkboard can represent the place where the sound starts, and a line at the other side can stand for a wall. Use a string radius to draw a series of concentric circles that are expanding. When the largest circle reaches the "wall," use another color of chalk for the pattern of returning waves. Why does it take time for an echo to return? This question prompts the realization that sound takes time to travel—just as the waves in a rope or a Slinky or water do; and it leads to the next section.

Sound travels approximately 1,100 feet per second in air.

Equipment and Materials

. . . two flat boards
. . . a distance of 200 feet or so

How fast is sound? To see for yourself that sound takes time to travel, find two flat pieces of wood that make a sharp crack when slapped together. Ask a child to carry them to a far corner of the playground. As he makes a sound with them, do you see the wood come together before you hear the sound? What other evidence that you know of indicates that sound takes time to travel?

Does the pitch of the sound make any difference in the speed of the sound? Play a low note, then a high note, then a chord, on an autoharp or a piano. Do the different pitches in the chord reach your ear at the same time? What would an orchestra or a band sound like if the lowest notes of the tuba or bass viol trailed along behind the highest notes of the piccolo? How do you know that the different pitches from an orchestra travel at about the same speed? Do loud sounds travel more quickly than soft sounds? You might return to the water waves and observe (with the aid of a watch) if there is any difference in the time it takes waves of different sizes to cross the dishpan.

Sound can be absorbed.

Stopping the bounce. Why is it satisfying to sing in the shower? Your voice sounds fuller and richer than usual, of course, as the sound bounces back from the walls around you. Try calling or speaking into a metal bucket or some other deep vessel. Why is the sound loud? Your sound waves come bouncing back almost as soon as you make them. They add up, like people singing together. What change can you hear if you stuff a towel or some paper into the bottom of the container? To see how the sound is reduced, return to your water waves. Put up a small fence of coarse screening or hardware cloth about half way across. What happens to a wave when it meets this fence? The small openings reduce its energy a good deal. Can you explain how acoustical tile on ceilings reduces the bounce of a sound wave?

Equipment and Materials

. . . metal bucket or wastebasket
. . . towel or paper
. . . coarse screening or hardware cloth

Extending the Concept

Focusing sound. A concave shaving mirror can be used to reflect sound waves to a point, focusing them so that they are heard more distinctly. Set up the watch a few inches in front of the mirror. Explore the space farther away with your ear and find the spot where the ticking is loudest. Does removing the mirror make the ticking softer? A curved metal or china bowl may be used also.

Equipment and Materials

. . . concave mirror or curved metal or china bowl
. . . watch

Whispering galleries. Curved walls and ceilings sometimes reflect whispers to a surprising distance. Have you ever visited one of these "whispering galleries"? There are some well-known ones in the National Capitol, Grand Central Station in New York, the Mormon Tabernacle at Salt Lake City, and Saint Paul's Cathedral in London. How does a whispering gallery work?

Reviewing the Concept

(*Text pages 24–25*)

Before You Go On. 1. a 2. a 3. b

Using What You Know. 1. Line the room with material that will absorb sound, that is, material that will absorb the movements of air molecules as they carry sound energy. 2. The sound (which appeared at the same instant as the flash) took 5 seconds to reach the observer. Since sound travels about 1,100 feet in a second, the rocket must have been about 5 × 1,100 or 5,500 feet away; just over a mile, that is.

(*Text pages 25–27*)

CONCEPTUAL SCHEME
When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT
A loss or gain of energy affects molecular motion.

Section 6: THE MAIN CONCEPT: SOUND AND MOLECULES

Through experiences and observations, children have been introduced to sound as a form of energy. The transmission of sound has provided an opportunity to develop and extend the concept of the invisible world of molecules around us. Sound is seen as an orderly, predictable motion of molecules. How the control of sound depends on knowledge of the nature of sound is brought out. Relationships to music and to health are suggested.

How is sound made?
How does sound travel?
How fast does sound travel?

CONCEPT SUMMARY

You may want to ask the children themselves what they think are the big ideas of this unit. What have they learned about sound? What do they now know about sound that they did not know before? What do they think are the most important ideas about sound? They may mention these ideas:

—Where there's sound, there's vibration.
—Pitch depends on speed of vibration.
—Sound travels in waves, by molecular movement.
—Sound waves can bounce and make echoes.
—Sound waves can travel faster in a solid than in air.
—Sound travels at about 1,100 feet per second.

What do they think is the most important idea about sound that they have learned? This is a difficult question, to be sure, and perhaps not entirely fair, for ideas are interconnected, and it may be hard to single out one as more important than another. Yet it may be felt that the idea of molecules in motion underlies these other ideas, that the molecular theory is basic to these other ideas and therefore, perhaps, more important.

What is a theory?

You may want to recall that something has been learned about the nature of a theory—an important part of science that will be encountered again.

Why do scientists investigate?

What is the importance of an investigation? You may want to ask the children some such question. A clue to an answer is given in the phrase "See for yourself . . ." used to introduce an investigation in the text. Scientists consider it most important to "see for yourself." When they have reasoned out a likely answer to a problem, they have to see for themselves, by an experiment (or investigation), whether the answer does work.

(*Text pages 26–27*)

FIXING THE MAIN CONCEPTS

Testing Yourself. **1.** a **2.** a **3.** b **4.** b **5.** b **6.** a **7.** b **8.** b **9.** a **10.** a

About This Book

Imagine that you are walking along one day and see something shining on the ground. You pick it up and look at it. It is a stone, but one you have in your collection. You toss it back. Instead of falling to the ground, the stone starts to rise. It rises faster and faster, higher and higher, out of sight!

Of course you would be astonished. Anyone would be. We expect stones to fall *down*, not up. They always have. It is a regular event for stones to fall down, just as it is for winter to follow summer.

We depend on regular events, don't we? It would be a strange world if you could not tell what was going to happen when you started to pour milk into a glass or pushed a door to open it. It would be so strange a world, if regular events stopped being regular, that we could not live in it.

This book is about regular events. It is about events that can be predicted because scientists have found out what makes them regular.

UNIT ONE

THE BOUNCE OF SOUND

Think for a moment about how many different sounds you hear around you every day.

The tick of a clock. The roar of a jet plane. The bark of a dog. A friend's voice. Wind in the trees. The rumble of thunder. The twang of a guitar. A door closing. The squeak of chalk on the board. The thud of a bass drum. The rustle of paper. A sneeze. A cat's purr. The patter of rain. Bells and buzzers. Auto horns. What other kinds of sounds would you add to the list?

No matter what sounds you add, no matter how different they seem, they are all alike in one way.

How are all sounds alike? Let's investigate.

■

1. Making a Sound

What is a sound? How is a sound made? Let's look for some answers to these questions. Let's look for answers as scientists do. This is a book about how scientists look for answers to questions, and what scientists find out.

There are different ways of answering a question, you know. If you ask an artist "What is sound?" he might paint you a picture for an answer. If you ask a composer what sound is, he might compose a piece of music for his answer. If you ask a doctor what sound is, he might tell you what sound does to your ear. If you ask a scientist what sound is, what will he say? We are going to look at the answer that scientists give. We are also going to see how scientists look for answers, for scientists have special ways of looking for answers.

What do scientists do when they look for an answer to a question? As you go on, you will do some of the things that scientists do. You will observe. You will investigate. You will reason about what you see and try to explain it. This is what scientists do. They try to find explanations for what they see. So will you.

You will wonder about things. A scientist wonders about things, too. Then he investigates. He sees for himself.

How is a sound made? See for yourself. Do the investigation on the opposite page.

Sound and Movement

The rubber band makes a sound. The ruler makes a sound. When they make a sound, they *move.*

Putting a finger on the moving rubber band stops the movement. The sound stops too. Stopping the moving ruler stops the sound there, too.

It seems that to make a sound, the rubber band and the ruler must *move.*

This is true for more than rubber bands and rulers. Touch a bell when it is ringing. You will feel the metal moving. ■ See the picture marked with a square.

AN INVESTIGATION into the Making of a Sound

Needed: a ruler, a rubber band, a pie tin or saucer

Stretch the rubber band around the pie tin or saucer.

Pluck the rubber band with a finger so that it makes a sound. ■ See the picture marked with a square. What does the band do while you hear the sound? ●

What does the rubber band do as the sound dies away and stops?

Pluck the rubber band. Before the sound dies away, put your finger on the band. What happens to the band? What happens to the sound?

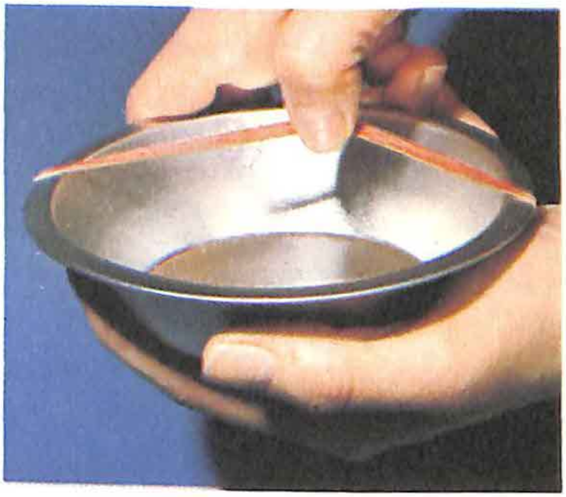
Hold down one end of the ruler firmly, and pluck the free end. ▲ What does the ruler do while the sound is heard?

Pluck the free end of the ruler again. Before the sound stops, stop the ruler with your hand. What happens to the sound?

Can you make a sound with the ruler or the rubber band without its moving?

Now look closely at the ruler when it is making a sound. The ruler will move more slowly if you make the free end long. *How* does it move?

How does the rubber band move?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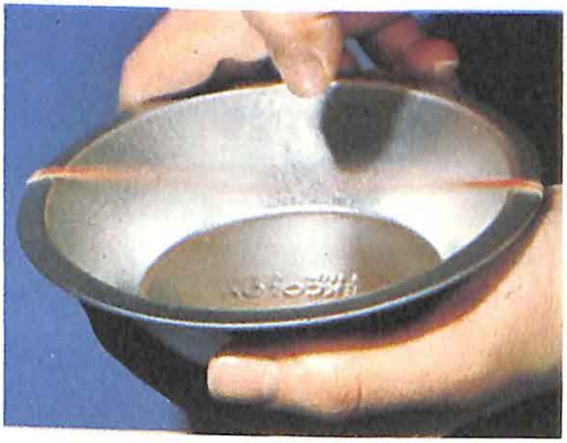
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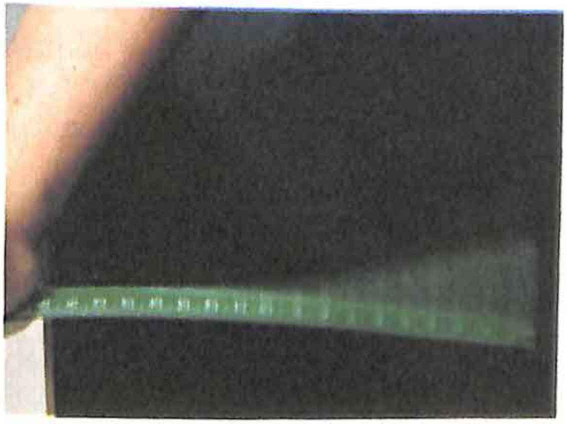
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Put your finger lightly on a sounding piano string. You will feel it moving. Touch the string of a double bass or a guitar while it is sounding. You will feel it moving. Touch a drumhead just after the drummer has hit it. It is moving.

The trumpet player's lips move when he blows air into his trumpet. Inside your throat there is something that moves when you make a sound. Put your hand on your throat, sing "ah," and feel the movement.

Wherever there is a sound, something is moving to make that sound. Many investigations and experiments, by many scientists, have shown it is so.

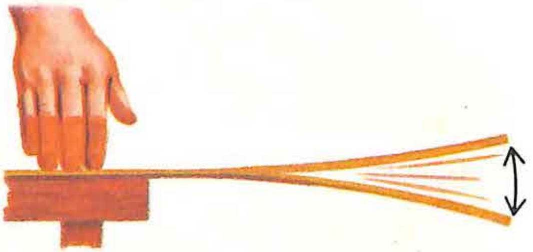
Think again of all the different sounds you can hear. Yet no matter how different the sounds are, they are all alike in this.

To make sound, something moves.

To and Fro

To make sound, there must be movement. What kind of motion must it be?

■



Could you see how the ruler moved as it made a sound? It moved up and down. It swung one way and then the other way, to and fro. ■

Could you observe how the rubber band moved as it made a sound? It swung back and forth, to and fro. ● If you wish, you can see this movement in slow motion. Make a chain of rubber bands about 2 feet long. Fasten one end to a doorknob or table leg. Stretch the chain just a little and pluck it. It will move to and fro, slowly enough for you to see.

It is this to-and-fro movement that makes sound. Scientists have a name for this kind of movement. It is called **vibration** (VY·BRAY·sh'n). The rubber band vibrates as it moves to and fro and makes a sound. The ruler' vibrates as it makes a sound. A piano string and a guitar string vibrate as they make sounds. The trumpet player's lips vibrate. The bass drum vibrates. Inside your throat something must vibrate in order for you to speak or sing.

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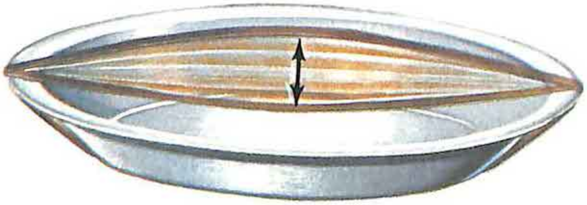

Whenever you hear a sound, something is vibrating. Something is moving back and forth.

Does this mean that whenever something is vibrating, you hear a sound? Try it and see. Vibrate your hand, like a fan. Vibrate the chain of rubber bands in slow motion. No sound is heard. Things can vibrate without making a sound.

Whenever you hear a sound, however, something is vibrating.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Whenever there is a sound, something is
   a. moving   b. being plucked
2. When a thing vibrates, it moves
   a. very quickly   b. to and fro
3. As you sing, something in your throat
   a. vibrates   b. stops vibrating

USING WHAT YOU KNOW

When a ball hits a tennis racket, there is a sound. What might be vibrating?

ON YOUR OWN

Get a thick rubber band and a thin rubber band of about the same length. Hook one end of each rubber band over a doorknob. Stretch both bands the same distance. Pluck each band. What do you observe?

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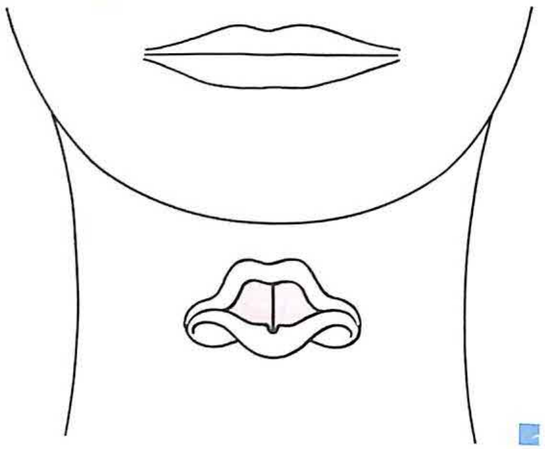


2. High and Low

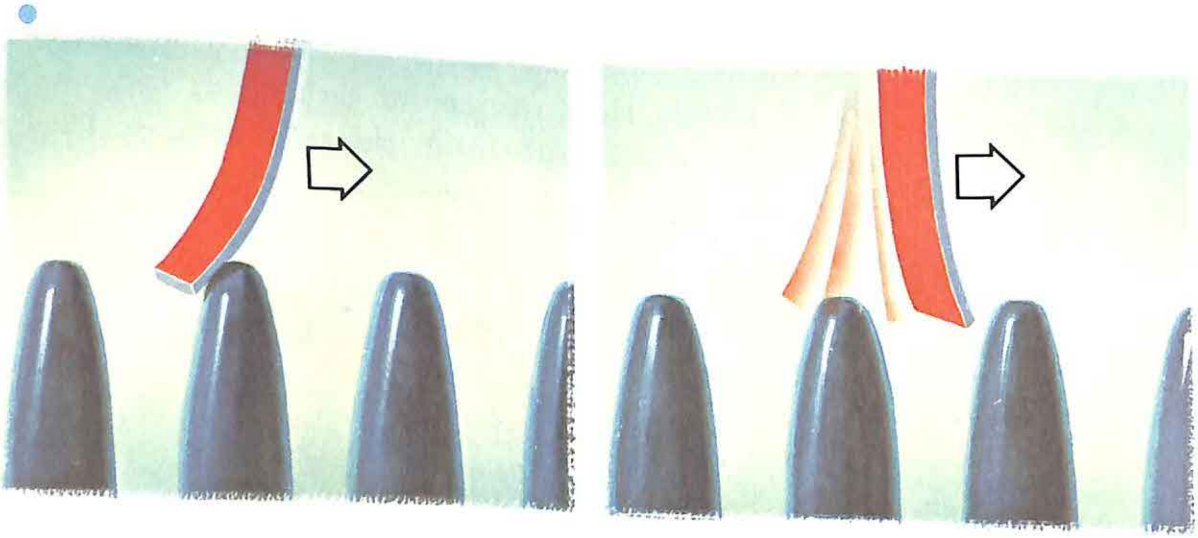
Put your hand on your throat and hum a note. You can feel something vibrating in your throat and making the sound. Your vocal cords are vibrating, right inside your throat. ■ When you speak or sing or hum, your vocal cords vibrate to make the sound.

Hum as high a note as you can. Hum as low a note as you can. We say that the high note has a high **pitch.** The low note has a low pitch. When you change from one note to another, the pitch changes.

You can feel muscles in your throat moving as you change pitch. What are your vocal cords doing that makes the pitch of the sound change? You can find out with the help of a comb and a piece of cardboard. Try the investigation on the opposite page.

Fast and Slow

What happens as you draw a piece of cardboard very slowly along the teeth of a comb? The cardboard catches on a tooth and is pulled back a little. Then the cardboard slips off the tooth and springs forward. The next tooth pulls the cardboard back again. Back and forth goes the edge of the cardboard along the comb. ●



AN INVESTIGATION into High and Low Pitch

Needed: a comb, a piece of thin, stiff cardboard

Hold the comb in one hand and the cardboard in the other, like this. ■ Hold the cardboard lightly but firmly.

Pull the cardboard slowly and steadily along the teeth of the comb. ● Listen to the pitch of the sound that is made.

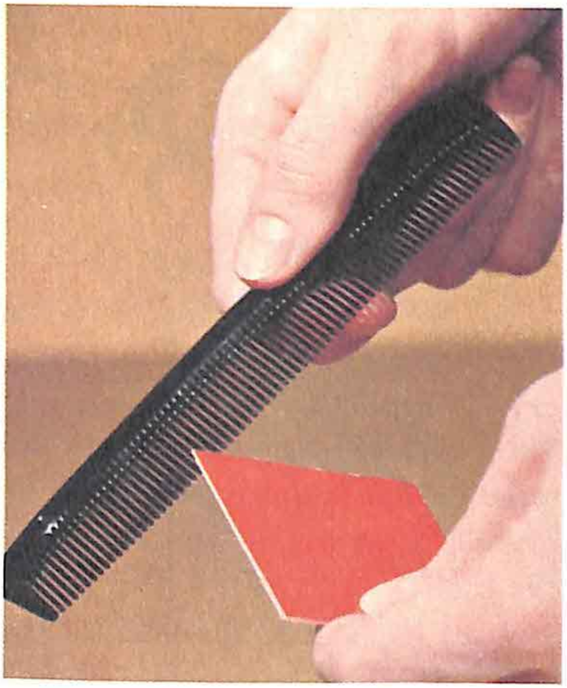
Now pull the cardboard faster along the teeth. What happens to the pitch of the sound? Does the pitch change? Does it get higher or lower? Listen carefully.

Move the cardboard along the teeth of the comb at different speeds until you are sure what happens to the pitch.

Now draw the cardboard along the teeth very slowly. Observe what happens to the cardboard. How do the teeth make the cardboard vibrate?

Moving the cardboard quickly along the comb makes fast vibrations. Moving the cardboard slowly makes slow vibrations.

What happens to the pitch when the vibrations are slow? What happens to the pitch when the vibrations are fast?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The cardboard is vibrating. You can make it vibrate slowly or quickly by moving it slowly or quickly along the comb.

What happens to the pitch of the sound the cardboard makes? It isn't a very clear pitch, certainly, but it does change. As the vibrations get faster, the pitch goes higher. As the vibrations get slower, the pitch goes lower.

The higher the pitch of the sound, the faster the vibrations that make the sound. The lower the pitch, the slower the vibrations. This holds good for *all* sounds, not just for combs and cardboard. When you hum a high note, your vocal cords are vibrating faster than when you hum a low note. The squeak of chalk on the chalkboard has a very high pitch, made by very fast vibrations. The lowest note on a piano comes from a string that is made to vibrate slowly.

The buzz of a mosquito has a higher pitch than the hum of a bee. Their vibrating wings make the sound. ■ Which one's wings are vibrating faster?

Changing the Pitch

Take a piece of thick, heavy string about 2 feet long. Tie one end to something firm, such as a doorknob. Pull the other end hard and pluck the string. Is the pitch of the sound low or high? Take another piece of string about 2 feet long, but thin and light. Stretch it tight. But before you pluck it, make a guess. Will its pitch be higher or lower than the heavy string?

The thinner string can vibrate more quickly than the thicker one. Its pitch will be higher. The thicker string, being heavier, moves more slowly. Its vibrations are slower. Its pitch is lower. You may have noticed that the strings that make the low notes on a piano or a guitar or a double bass are thicker and heavier than the other strings.

Perhaps you have already found out that tightening or loosening a rubber band stretched around a pie tin or saucer made its pitch change.

This is another way of making vibrations go faster or slower. Tightening a string makes it vibrate faster, and loosening it makes it vibrate slower. You may have seen a violinist tighten or loosen a string.

There are still other ways of changing the pitch of a sound. You can be sure of one thing about all of the ways, however. In order to change the pitch, the speed of the vibrations must change.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A policeman's whistle makes a high sound. We say the whistle has a

   a. high pitch

   b. low pitch

2. As the pitch of a sound goes lower, the vibrations go

   a. faster

   b. more slowly

3. The thickest and heaviest string on a guitar plays

   a. the highest pitch

   b. the lowest pitch

USING WHAT YOU KNOW

A bass viol can make a sound of very low pitch. A violin can make a very high-pitched sound. Why?

ON YOUR OWN

Make a stringed instrument using rubber bands. Make your instrument with rubber bands placed in such a way that you will get low-pitched and high-pitched sounds.

3. Pushing and Pulling Molecules

You see a friend on the other side of the street. Your friend does not see you. "Hi," you call. Your friend turns around.

What makes your friend turn around?

When you call "Hi," your vocal cords vibrate. Their vibration makes sound. But your friend is some distance away. How does he know that your vocal cords are vibrating, when you are on the other side of the street? How do the vibrations get from you to him?

Try the investigation on the opposite page. It will give you a clue to the explanation.

Waves

A **wave** can be sent along a rope by flipping the end of the rope. Flip the end of the rope quickly three or four times, and three or four waves will run along the rope, one after the other. Isn't this flipping movement a vibration? You can send waves along a rope by vibrating the end of it.

Dip a finger in calm water. Move the finger back and forth. You can send waves in water by vibrating a finger in the water. ■ See how the waves spread out from the vibrating finger, in every direction in the water.

When a rubber band is stretched around a dish and plucked, the band vibrates. Is the rubber band vibrating *in* anything? Of course it is. The rubber band is vibrating *in air*.

■

AN INVESTIGATION into Waves

Needed: fifteen or more feet of clothesline or other light rope

Tie one end of the rope to a firm support such as a chair leg. Hold the other end so that the rope hangs just above the floor. ■

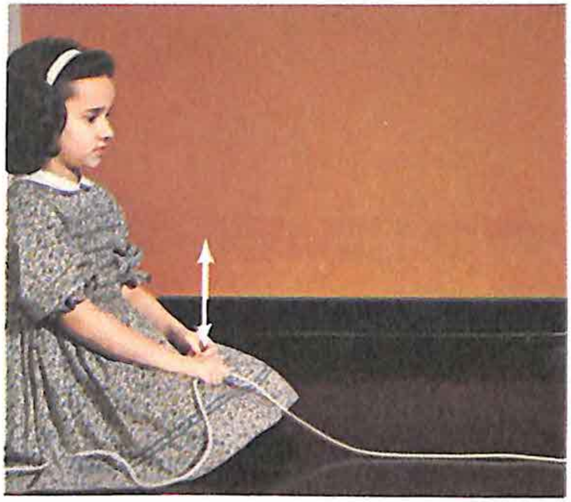
Now move your hand forward and back quickly, like this. ● You will make a kind of half-loop in the rope. What happens to the loop? ▲ ◆

The loop travels down the rope in a wave.

Try sending more waves along the rope. You will find that with practice you can send a wave rippling along the whole length of the rope.

When you flip the rope, the movement travels along the rope as a wave.

How many waves can you send along the rope, one after another?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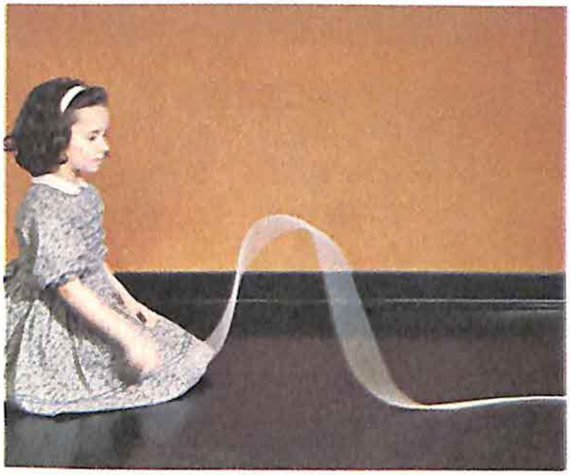
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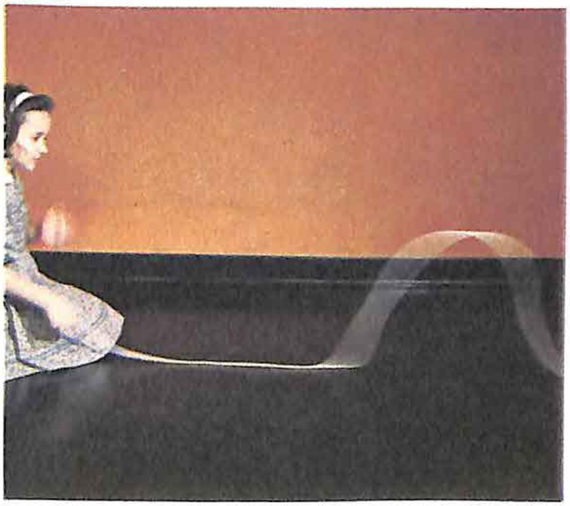
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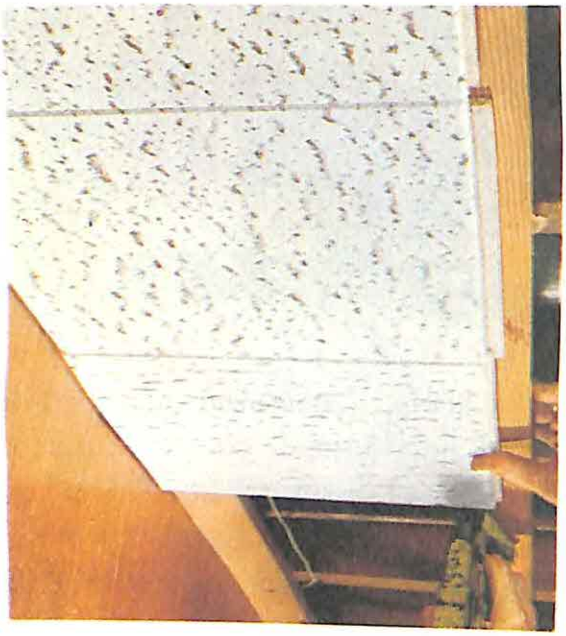

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you cannot make it out. You cannot hear an echo from a close wall, even though sound waves bounce from it.

Stopping the Bounce

You will not hear an echo when sound bounces from walls close to you. If there is a lot of sound, however, and it bounces from the walls, you may find the room noisy. You may wish that the sound did not bounce so much.

Now that we know what sound is and how it behaves, we can control it better. If we do not want the molecules of a sound wave to bounce off a wall, we hang soft curtains on the wall. The moving molecules in the air sink in among the molecules of cloth and do not bounce. We say that the cloth **absorbs** (ab·ZORBZ) the sound.

To absorb sound, the walls and ceiling of a noisy room may be covered with tiles like these.■ Notice the holes in the tile. Molecules of air that hit where these holes are cannot do much bouncing. So the bounce of a sound wave is cut down by this sound-absorbing tile. The molecular theory is very useful when it comes to designing sound-absorbing materials like these.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. An echo happens because sound waves
   a. can bounce off walls b. cannot bounce off walls
2. Sound travels at a speed of about
   a. 1,100 feet a second b. 1,100 feet a minute

3. When a sound wave hits a hard smooth wall, the wall
a. absorbs the sound b. bounces the sound back

USING WHAT YOU KNOW

1. A builder wants to make a room that is soundproof. What do you suggest he do? Explain by using the molecular theory.

2. You see the flash of an exploding skyrocket in the night sky. Five seconds later you hear the bang. About how far away was the rocket?

6. The Main Concept: Sound and Molecules

What makes a sound?

We know that when we hear a sound, something is vibrating. We know that these vibrations are making waves in the air. We know the waves are traveling through the air to our ears from the thing that is vibrating. We know that when the vibration stops, the sound stops too.

What else have we found out about sound? The faster a thing vibrates, the higher the pitch of the sound. The slower the vibrations, the lower the pitch. A policeman's whistle makes a sound of high pitch. A tuba makes a low-pitched sound.

We know that sound travels through the air at about 1,100 feet in a second. Because it does, and because sound bounces off a hard surface, it can make an echo. We know that an echo is a sound that has traveled away from us and bounced back.

We know these things because we have been studying sound. Yet we have really been studying about how molecules behave.

The Movement of Molecules

When we hear a sound we know that something is vibrating and passing its vibrations to the air around it. Air is made up of molecules, however. It is the molecules in air that pick up the vibrations. It is the molecules in air that pass the vibrations along.

Molecules next to the vibrating object are pushed by the object as it vibrates. Those molecules push the molecules next to them. So the push is passed along from one molecule to the

As the rubber band vibrates, it sends out waves in the air around it.■ Notice how the waves spread out in every direction. When these waves beat against your ear, you hear the sound of the vibrating rubber band.

When something vibrates in the air, it makes waves. The waves travel through the air.

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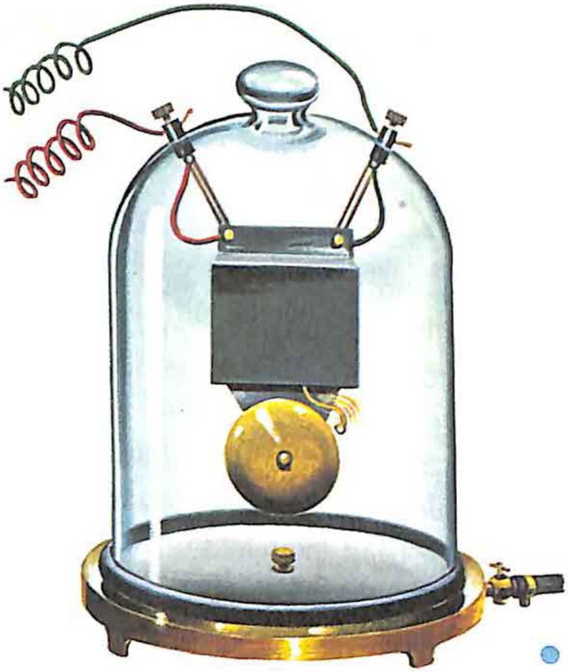

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Sound waves are carried by the air. If this is so, then taking away the air ought to mean that no sound can be heard. Here is a way of doing just that. This electric bell is hanging inside a glass jar.● There is air in the jar. When the bell is turned on, it can be heard ringing inside the jar. What if the air is removed?

Now the pump connected to the jar is started. The pump takes the air out of the jar, little by little. As it does, the sound of the bell becomes softer and softer. Finally, the bell cannot be heard. No air means no sound waves.

When you call "Hi" to a friend, your vocal cords vibrate and make waves in the air. The air around you carries these sound waves to your friend's ear.

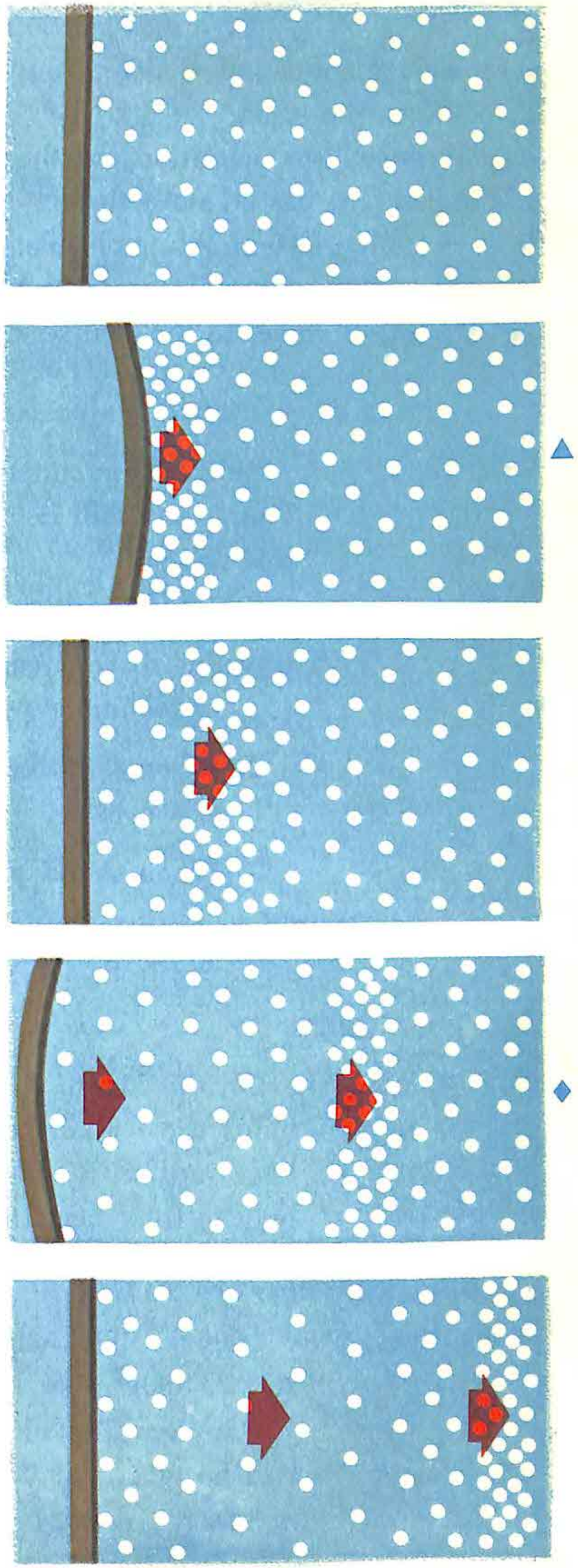
Bouncing Molecules

When a drummer hits his bass drum, a sound wave travels through the air. When a cricket chirps, sound waves travel through the air. When a tight rubber band is plucked, sound waves travel through the air. What happens to air when it carries a sound wave?

Air, you know, is made up of **molecules,** tiny specks of matter. The molecules in air are too small to see, even with the most powerful microscope. But let us imagine that we can see the molecules air is made of and that they look like tiny balls. What happens to them when a rubber band vibrates?

The rubber band swings to one side as it begins vibrating. It pushes against the air molecules on that side.▲ The molecules are crowded together. They push against the molecules next to them. Those molecules push against the next ones. So the push travels along, from molecule to molecule. It travels away from the vibration that started it.

Now the rubber band swings back the other way.◆ It leaves an empty space where it was. The molecules that have been pushed away rush back toward the rubber band. The molecules next to *them* rush back, and



so the movement is passed along from molecule to molecule.

In this way the vibrations of the rubber band are passed along through the air from molecule to molecule. This movement of molecules, to and fro, is a **sound wave.** In the next section we shall learn more about the movement of molecules. Because of the molecules, sound travels through the air. Do you think that sound will travel through a solid—through iron or wood, for example? We shall investigate this question next.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. When you hear the telephone ringing, sound waves are traveling to your ear through

a. telephone wires b. air

2. When a rubber band vibrates in air, it makes

a. waves b. molecules

3. When sound travels through air, the molecules in the air

a. move to and fro b. do not move

USING WHAT YOU KNOW

On the Moon, where there is probably no air, two astronauts are walking one behind the other. The astronaut in back raps on his own helmet with his hand. Will the astronaut in front hear the rapping? Why?

ON YOUR OWN

Use a coiled wire spring (Slinky) to show how waves travel. Show your model in class.

Can you think of a way to show how the pitch of a sound can be changed? For example, you might use glasses and water. If you do, try to explain the change in pitch.

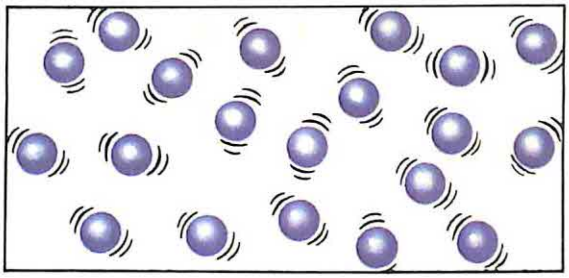
4. Sound and Molecules

The idea that things about you are made up of molecules explains a lot. For instance, soon after a drop of perfume is put on a dish, perfume can be smelled in every part of a room. The idea of molecules explains this. We can imagine molecules of perfume leaving the drop on the dish, jumping into the air, and mixing with the molecules in the air. Since all the molecules are moving about and bumping into each other, the molecules of perfume soon travel to all parts of the room.

There are many other things that the idea of molecules helps to explain. Scientists call this kind of idea a **theory** (THEE·uh·ree). A theory explains many different things. The idea that things are made up of molecules is a theory. It is called the *molecular* (muh·LEK·yuh·lar) *theory.* Let us see what use we can make of the molecular theory, the theory that all the things about us are made up of molecules.

Using the Theory of Molecules

We used the molecular theory to explain how perfume spreads. Let us use this theory to explain something different.



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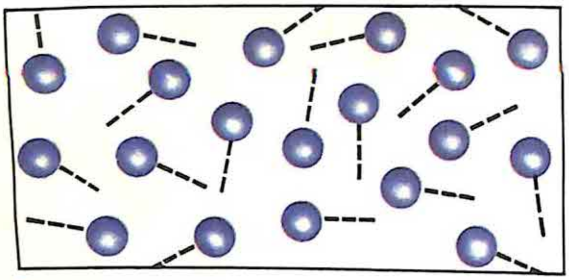
When you turn on a faucet, water pours out. Water is a **liquid.** Put some of this liquid in a tray, and put the tray in a freezer. In a while the water turns to ice. The liquid has become a **solid.** How is the solid different from the liquid?

Take some more liquid and put it in a pot. Heat it and let it boil. In a while the water boils away. It disappears because the water turns into an invisible **gas** and mixes with the air. Now the liquid has turned into a gas. How is the liquid different from the gas?

Water can be a solid. Water can be a liquid. Water can be a gas. What makes the difference? Let us see how the molecular theory explains the difference between a solid, a liquid, and a gas.

In a solid the molecules are close together. ■ Each molecule can move a little, from side to side. Each stays in its place, however. It cannot move away easily. A solid has a shape of its own.



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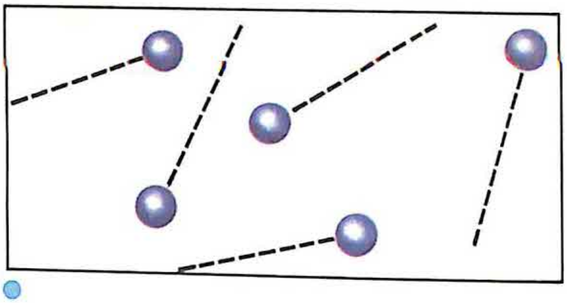

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In a liquid the molecules are farther apart than in the solid. ■ Each molecule can move easily. And the molecules can slide over each other, like marbles poured from a bag.

In a gas the molecules are very far apart. ● Each molecule can move about freely.

This is how the molecular theory explains the difference between a solid, a liquid, and a gas.

Let us put the molecular theory to another test. Let us observe what happens when sound goes through a solid. Then we will see if the theory of molecules can explain what happens. Try the investigation on the opposite page.

The Theory Helps

A string telephone shows that the sound of a voice travels better through the solid string than through air. A pencil tapping on a wall shows that sound travels better through the solid wall than through air, which is a gas. Many investigations and experiments have shown that sound does travel better through a solid than through a gas.

Why does sound travel better through a solid? Let us see if the molecular theory suggests why.

It is the to-and-fro movement of molecules that carries sound. Molecules bump their neighbors. The neighboring molecules pass on the bump to *their* neighbors, and so on. The molecules of a solid are close together. The molecules of a gas are far apart. Which molecules can bump each other more easily? Those that are close together, surely. If molecules bump more easily, they can carry sound better.

So the molecular theory does suggest an explanation. The theory is useful. This is what theories are for, and this is why scientists value theories so much. A good theory can explain many puzzles, in many different places. Because theories are so helpful, you will see the molecular theory used to explain other puzzles.

AN INVESTIGATION into Sound in a Gas and a Solid

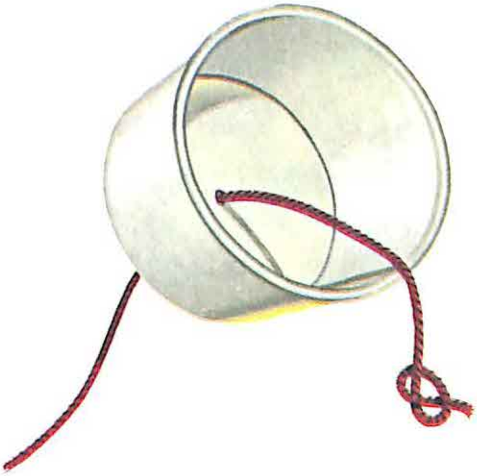
Needed: about 10 feet of string, two paper cups, a wall, a pencil

Make a small hole in the bottom of each cup with the pencil point. Put one end of the string through the hole and knot the string so that it cannot come out. ■

Have a classmate hold one cup to his ear. Stretch the string tight, and whisper some numbers into the string telephone. ● Your classmate should repeat them aloud, to show that he has heard them. Then whisper some numbers without using the string telephone. Does your classmate hear them? Which carries sound better, the string or the air?

Put your ear against a wall. Have someone tap the wall from some distance away with the eraser end of a pencil. As the tapping goes on, lift your ear from the solid wall so that the sound reaches you through the air.

Which sound is louder, the one carried through the gas or the one carried through the solid?



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BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. An idea that explains many different things is called a
   a. model b. theory

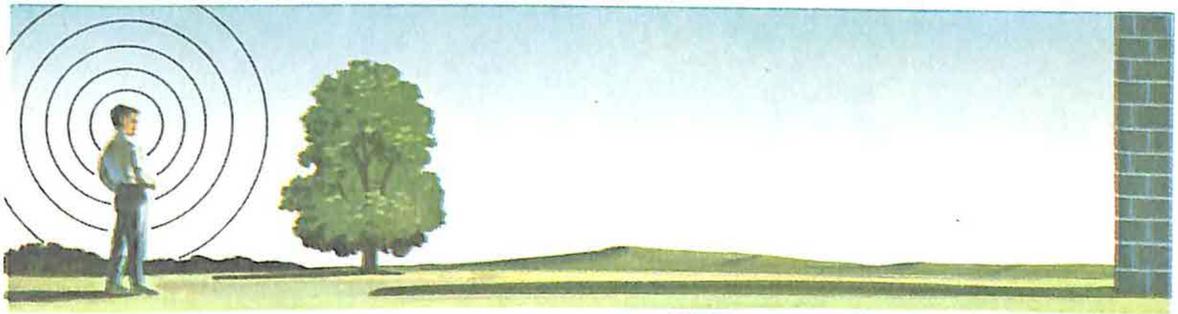
2. According to the molecular theory, the molecules in a liquid
   a. are fixed in place b. can slide over each other

3. Sound travels faster in a solid than in a gas because the molecules in a solid are
   a. closer together b. farther apart

USING WHAT YOU KNOW

1. An Indian would put his ear to the ground to hear distant horses. Why was this a good way to hear sounds?

2. Do you think that sound would travel faster in air or under water? Why?



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5. When Sound Returns

This is a famous place in Zion National Park in the state of Utah. ■ If you call "Hello" across the valley, in a few seconds a ghostly voice will answer "Hello." "Who are you?" you call. Back comes the reply, "Who are you?" Whatever you call, the voice repeats exactly. You may notice that it replies in just the same tone, too. If you call out a long sentence, the voice will begin the reply before you have finished. It always repeats what you say. It is an **echo.**

Echoes are not found just anywhere, as you know. Why are echoes found in certain places? What makes an echo?

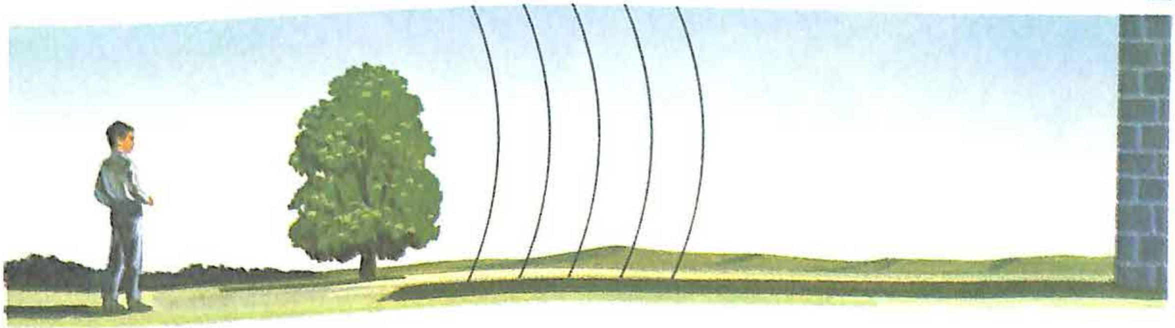
People who lived in Greece more than 2,500 years ago explained echoes this way. There was a girl named Echo, they said, who was in love with a certain young man. He did not love her, however, so she faded away until nothing was left but her voice. It is Echo, said the Greeks, who calls back.

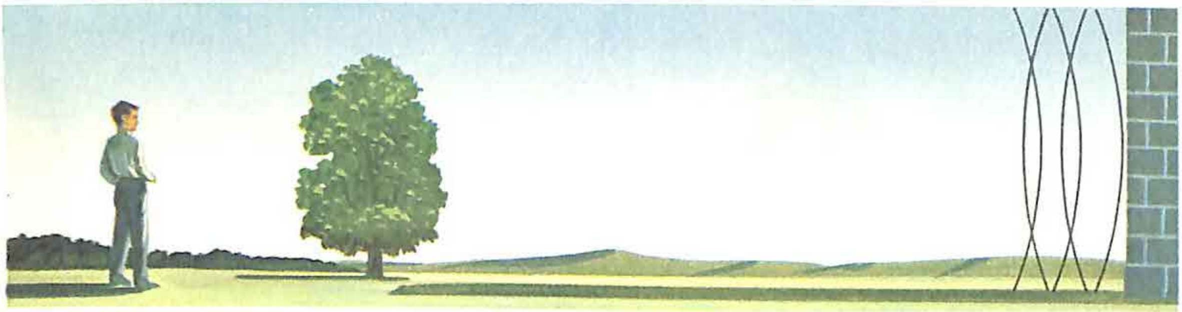
We have kept the girl's name, as you see. However, we have a different explanation of what makes an echo.

Why Sound Returns

You shout "Hello!" ● Your vocal cords vibrate. Waves of sound come from your mouth and travel through the air. ▲ Some distance away is a brick wall. The sound waves hit the

▲





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wall. What happens? The waves *bounce* off the wall. ■

Now the waves head back. ● In a short time the returning sound waves reach your ears. You hear "Hello" softly. It is an echo. ▲

An echo happens when sound waves bounce. What is across the valley in the picture on page 20? The hard stone wall of a steep cliff. So the sound waves of a "Hello" travel across the valley to the cliff. They bounce off the side of the mountain. They come back across the valley. The person who shouted hears an echo.

Remember that a sound wave is made up of molecules in the air moving forward and backward, to and fro. The mountain is made of molecules, too. However, the stone in the mountain is a solid. Its molecules are packed close together. The molecules in the air are far apart. They bounce off the molecules of stone.

One thing that is needed for an echo, then, is something for sound to bounce off. If you could visit all the Echo Lakes and Echo Valleys and Echo Mountains in the world, you would be sure to find that each has a wall of some kind off which to bounce the sound and make the echo.

How Fast Is Sound

It takes more than a wall and a shout to make an echo, however. Perhaps there is a wall near you now. If you say "Hello" to it, you won't hear

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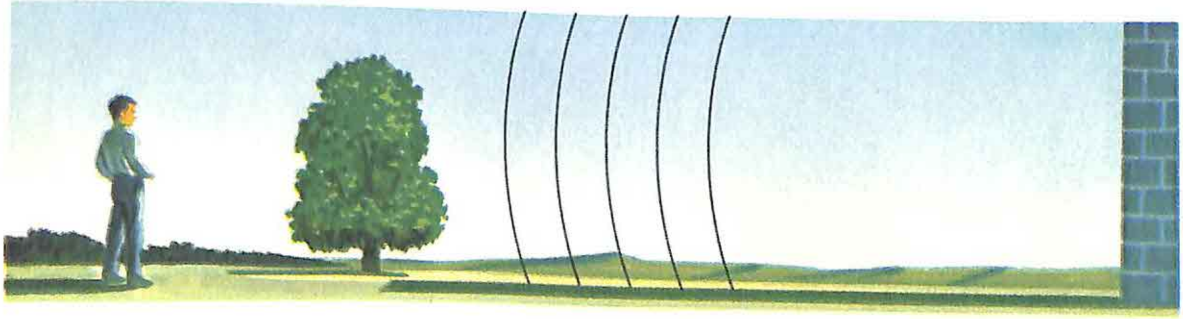

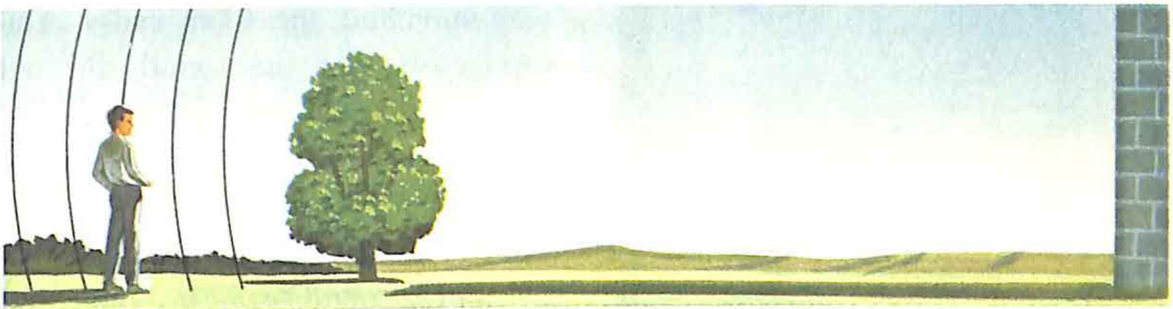

an echo; and you still won't, even if you shout "Hello." Why not?

Let us go back to the cliff again for a moment. When you shout "Hello" there, it takes 6 or 8 seconds for the echo to return. In that time the sound waves travel across to the cliff, bounce, and come back. Do you see what this means? *It takes time for sound to travel* across the valley and back.

It takes time for sound to travel. Of course it does, now that you think of it. You hear the sound of the bat hitting the ball *after* you see it, when you are some distance away from the batter. It takes time for the sound waves to travel to you. Have you noticed that you can see a distant bass drummer hit his drum before you hear him? It takes time for sound waves to travel. It takes time for the bumping of molecules to pass along through air.

How much time does it take? After many investigations and experiments, scientists have measured the speed of sound. Sound travels about 1,100 feet in 1 second of time. That's about as long as four football fields.

If there is a watch or clock with a second hand nearby, count off some seconds. "One . . . two . . . three . . . four. . . ." When you are saying "two," how far has the sound of "one" traveled? It has sped about 1,100 feet away in that second of time. By the time you are saying "three," that first sound is 2 × 1,100 feet away, or 2,200 feet.

Suppose that the face of the cliff is exactly 1,100 feet away. How long will it take a "Hello" to get to the mountain? About 1 second. How long will it take that sound to come back? About 1 second. So the total time for the trip, going and returning, will be about 2 seconds.

If you say "Hello" to a wall close to you, the sound does bounce from the wall. But it goes to the wall and returns to you in so little time that next. Each molecule moves back and forth in its place as it passes the vibration along. What if the molecules could not move? The sound would not be passed along. There would be no sound waves. If molecules did not bounce, there would be no echoes. If molecules were not able to move fast or slowly, there would be no difference in pitch.

We have really been studying how molecules behave when something vibrates, even though we have never seen a molecule.

Fixing the Main Concepts

TESTING YOURSELF

Study the statements below and choose the correct responses. Your study will help fix in your mind the main concepts of this section.

1. The molecular theory helps us to explain
   a. sound b. everything
2. A very fast vibration of a string results in a sound of
   a. high pitch b. low pitch
3. A low-pitched sound is heard. The object making the sound must be vibrating
   a. rapidly b. slowly
4. When you speak, your vocal cords are
   a. quiet b. vibrating
5. A sound wave travels fastest in a
   a. gas b. solid
6. An echo means that sound waves have
   a. bounced b. been absorbed

7. The motion of molecules when they carry sound is
   a. up and down   b. to and fro

8. It takes 2 seconds for a sound to come back from a wall. The wall is
   a. 1,100 feet away   b. 2,200 feet away

9. A wall with tiny holes in it is most likely to
   a. absorb sound   b. echo sound

10. Sound travels in solids more quickly than in gases because in solids the molecules are
   a. closer together than in gases
   b. farther apart than in gases

FOR YOUR READING

Through this book you can extend your knowledge of sound—*Sound: An Experiment Book*, by Marian Baer, published by Holiday House, New York, 1952. The author uses the word "experiment" in the same way the word "investigation" is used in your science book. You find in Marian Baer's book many simple investigations and some that are not so simple.

GOING FURTHER

Use your knowledge of sound to make a musical instrument out of eight pop bottles or water tumblers.

Unit Two

THE BOUNCE OF LIGHT

(*Text pages 28–54*)

UNIT CONCEPT
A loss or gain of energy affects molecular motion.

Children explore the nature of light and discover that simple investigations can reveal a surprising amount of information about how light behaves. They obtain a concept of light as a form of energy.

A VIEW OF THE UNIT

A Preview of the Concepts

Man once worshipped light, as a giver of life to all green things, and as a mystery beyond understanding. Light is still, in one way at least, a mystery that scientists have not yet fully solved. Yet scientists have managed to discover much about light: how it behaves, how it may be controlled and produced; and with this understanding man's concept of the nature of light has changed. How have scientists managed to gain this understanding? What have they discovered about light? This unit gives children a glimpse of the methods and results of science in the field of light, and a concept of the nature of light.

Reflection and Absorption

The unit opens by contradicting an easy assumption: that to see an object it is only necessary to shine a light on it. The fact is, an object must bounce light to the eye to be seen. Although there are objects that give off their own light (like the Sun or an electric lamp), most objects are seen by light that bounces off them. Yet there is a deeper meaning to this discovery: it tells us something about the nature of light. Light can bounce—that is, be reflected. Light can be absorbed, too, when it is not reflected.

Sound can be reflected and absorbed. Is light like sound, then? Some simple but revealing comparisons of how light and sound behave make it plain that although light and sound are alike in some ways, they are basically different in behavior. The mystery of light is not solved by way of sound, but more information about light is obtained, happily.

It is likely that some of the children in the class have already used a magnifying glass and sunlight to incinerate paper. But it is very unlikely that they have understood just what this procedure reveals about the nature of light, so the investigation with a convex lens and a bit of paper and sunlight (with a plate as a safe base of operations) is no mere repetition of a familiar event. The investigation reveals that light can be bent. So another bit of information about light is obtained, and used to explain some riddles of an interesting kind.

Light as Energy

The question of how light is made, and the example of a candle, leads to an important answer. Light is made by changing one form of energy into another form. Light is a form of energy. In the case of the candle, chemical energy is changed into light energy, as molecules change to different molecules in the flame. Development of the concept of energy continues.

The Travel of Light

If light is a form of energy, then, how does it travel from one place to another? We know that sound—another form of energy—goes from place to place by means of waves, and that the waves are carried along by the bumping of molecules. Does light energy travel by means of waves? Some evidence that suggests that this is so is offered in an investigation with polarized material, by way of a model. But it has to be added that this evidence is not all; that other evidence suggests that light sometimes behaves like a stream of particles, not waves. So scientists have two theories about the nature of light, and are still trying to solve this mystery.

In spite of this mystery, the concept that light is a form of energy remains. Being a form of energy, light can change into other forms of energy—chemical, mechanical, electric, heat, and so forth. Or light energy may be produced from other forms of energy. Above all, as a form of energy, light becomes a part of what scientists know about energy in general—a powerful addition indeed to our information about energy.

SUPPLEMENTARY AIDS

The full names and addresses of distributors and suppliers of films and filmstrips are on page F-25. All films and filmstrips are in color and rated on the intermediate level.

Films

How to Bend Light (11 min.), E.B.F., 1964. Proves that light travels in straight lines, that it can be bent by reflection or refraction, that we see objects because light hits them and is reflected back to our eyes; shows how lenses are used to magnify objects and focus an image.

Light and What It Does (11 min.), E.B.F., 1964. Demonstrates, through a series of simple problem-solving experiences, how light travels; what causes reflection and refraction; and how light is used in many everyday activities.

All About Light (11 min., with sound), Cenco, 1963. Explains how light travels; the sources of light, both natural and artificial; and how light waves can be separated into different colors called the spectrum.

Filmstrips

Light (49 frames), E.B.F., 1954. Animated drawings explain how light travels; the speed of light; the reflection, absorption, and refraction of light waves; the effect of lenses on light waves; the creation of a rainbow with a prism.

Light (40 frames), McGraw-Hill, 1952. Explains the basic characteristics of light; its source; reflection and refraction of light rays; how light travels.

Light and Color (43 frames), McGraw-Hill, 1959. Drawings show how light travels from its source; what is meant by reflection and refraction; how a prism breaks light into a spectrum; why objects have different colors.

Light and How It Travels (40 frames), Jam Handy, 1957. Demonstrates that the Sun is the most important source of light. Explains transparence, translucence, and what causes shadows; gives examples of how light waves are reflected and refracted.

Light and Color (40 frames), Jam Handy, 1959. Explains how different light waves are seen as different colors; the arrangement of colored bands of light waves, from red to violet, is called the spectrum; the length of the light wave determines the color; how the human eye sees light and color.

Science Reading Table

Starred (*) titles are especially recommended for content and reading level. Addresses of the publishers are on page F-24.

Color in Your Life, by Irving Adler, John Day, 1962. Explains the basic structure and characteristics of light. Includes description of the role of color in printing, television, and photography. Common examples of color, such as in soap bubbles and the sunset, relate the subject to easily observable phenomena. (Average)

**Exploring Light and Color,* by Charles D. Neal, Childrens Press, 1964. An outsize book in content and format. A young readers' encyclopedia of information and interesting investigations in the science of optics. From the first sentence "Did you ever try to do a job in the dark?" to the last page which contains a summary of the content, pupils will be drawn to this book. (Average)

**The First Book of Color,* by Herbert P. Paschel, Franklin Watts, 1959. An introductory treatment of the subject with highly colored illustrations. Describes basic properties of light and color; use of color in printing. (Advanced)

Junior Science Book of Light, by Rocco Feravolo, Garrard Press, 1961. Describes how light travels, how it is reflected, how shadows are made, and how light rays are bent. The camera, submarine periscope, and phenomena of nature are explained with the assistance of a few basic investigations. (Easy)

Prisms and Lenses, by Jerome S. Meyer, World Publishing, 1959. A concise introduction to the science of optics. In discussion of basic principles, reference is repeatedly made to the use of the principles in everyday life and in the work of the scientist. (Average)

What Is Light, by Theodore W. Munch, Benefic Press, 1960. The properties of light, difficult to understand, are dealt with in simple terms, supplemented with many pictures and illustrations. The material provides a brief survey of the subject including the sources of light, bending of light rays, lenses, the eye, and consideration of color. (Advanced)

**The Wonder of Light,* by Hy Ruchlis, Harper & Row, 1960. A comprehensive treatment of the properties of light. Comparisons and photographs supplement basic information. Covers a wide range of topics. (Advanced)

Your Eyes, by Irving and Ruth Adler, John Day, 1962. Basic principles of optics, anatomy, and physiology are explained. An introductory consideration of sight and light. (Average)

▶ INTRODUCING THE UNIT

The unit opening picture (page 28) shows a lighthouse on the coast of Maine. What is a lighthouse for? Its light can be seen several miles out at sea, and lets mariners who see the light know that their ship is approaching this rocky and dangerous coast. The number and length of flashes that the light makes in a minute tell mariners which lighthouse it is, and what part of the coast they are near. Why is light used for this task? It can be seen far off (in clear weather) at night when the warning is most needed.

After reading the unit opening on the opposite page, you may want to bring home to the children how much we depend on light, in this way. Place some objects in a paper bag without the children's seeing them. Invite some children to try to identify the objects while blindfolded. Include some objects that can be identified by smell, hearing, touch—and some that are difficult to name without seeing them. Compare the listed identifications with what can be seen when the bag is opened.

Section 1: WHEN DO WE SEE?

Children find that to see an object, light must shine on it and be reflected to the eye.

(Text pages 30–34)

SUBCONCEPT

Objects become visible as light is reflected from them to the eye.

Introducing the Concept

What's in this box? Invite a volunteer to look through a peephole punched in a shoebox that contains some familiar objects. The box is made as light-tight as possible by sealing it with tape. In the top of the box, opposite the peephole, is a larger opening to let in light, covered with a card hinged with tape to the box top. Open and close the light opening quickly, so that a brief glimpse is possible. Another volunteer may see a different object, in his turn. What is seen when the opening is shut? What is needed in the box in order to see the objects? (Light.) When there is no light in the box, do the objects disappear? (They do not appear; they are not seen. But the objects are still there.)

What then does light do that makes the objects visible?

After some guesses have been made, read Section 1, **When Do We See?** (page 30), as far as the investigation.

Equipment and Materials

. . . shoebox
. . . tape
. . . small objects
. . . piece of cardboard

Children begin to observe the behavior of light.

Developing the Concept

It might be thought that shining a light on an object is all that is needed to make the object visible, but the photographs on page 30

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show that this is not so. For the second photograph, the figure was painted with dull black paint. Its outline can just be made out, although the same light as before is falling on it. Why does painting with black paint make the object disappear? The investigation suggests the answer.

Light can be reflected and absorbed.

Equipment and Materials

See text page 31; also the Teacher's Manual for *Classroom Laboratory 4.*

Processes emphasized

Observation
Hypothesizing
Investigation (with design of an experiment)
Analysis of observations
Theorizing
Prediction
Reporting

The investigation. The book may be stood on a windowsill with its back or cover to the light, with the open page in the shade. When the mirror is used, the dark page will be pretty well lighted; the white paper will light the page only a little—but it will light it; and the black paper will not throw any light on the page at all. (Watch out that light from the children's clothes does not confuse the issue!) How is this behavior of light to be accounted for? Light is bouncing off the mirror to the book; bouncing off the white paper to the book, but not as well as from the mirror; and not bouncing off the black paper.

Can you show the path of the light that is bouncing from the mirror? The light entering and leaving the mirror may be interrupted by a hand in the beam, to show the path of the light. A little chalk dust from an eraser may make the beam from mirror to book visible in the shade.

It will be easy for the children to show that light-colored paper bounces more light than dark-colored paper. (They will note that colored paper bounces colored light, too.) From this you may want to go back to the lighted figure in the photographs on page 30. Why is it visible in one case, and not visible in the other? In one case, light is bouncing off the figure; in the other, no light is bouncing from the figure, and the figure is hardly seen. Why does painting the figure with black paint make it nearly disappear? The black paint stops light from bouncing.

Reflected light must reach the eye to be seen.

Equipment and Materials

- . . . flashlight or projector
- . . . white object
- . . . dull black object
- . . . sheet or cardboard

When light hits. The text explains what happens in the investigation, introducing the terms *reflected* and *absorbed.* What things in the room reflect light well? What things absorb light? (The darker an object, the less light it reflects and the more it absorbs.) You may want to darken the room and hold up in the beam of a flashlight or a projector a good-sized ball or other object painted white, then another painted dull black. What does the white object do to the light that makes it easy to see? What does the black object do that makes it hard to see?

Then to make the point that reflecting light is not enough for seeing, place the white object in the beam again. Is it reflecting light? (Yes.) Now place a book or piece of cardboard between the object and some of the children—but leave the object still brightly lit by the beam. Is the object reflecting light? (Yes.) But can you see it? (No, say the children behind the cardboard.) So reflecting light is not enough for seeing. What is needed? (The reflected light must reach the eye.)

Equipment and Materials

- . . . tennis ball
- . . . several books

Mirror and paper. To show the difference between regular and diffuse reflection, a tennis ball may be rolled across the floor so that it bounces off the smooth baseboard. If it is rolled at the same angle each time, it will be reflected at the same angle, all along the baseboard. Now place several books at angles along the baseboard, making an uneven surface. The ball will be reflected differently, depending on where it hits.

Extending the Concept

Equipment and Materials

- . . . large cardboard
- . . . comb
- . . . tape
- . . . mirror

An investigation into reflection. To see the regular way in which light is reflected from a mirror, cut a 1-inch hole near the bottom of a large square of cardboard. Tape a comb with large, wide teeth over the hole. Hold the cardboard facing the Sun, or tape it to a window through which the sunlight is shining. Stand a mirror in the beams of light from the hole so that the angles at which the beams strike the mirror are reflected and can be observed. By moving the mirror, it can be observed that beams hitting the mirror at a certain slant are reflected at the same slant.

Report on mirrors. There are interesting mirrors in focusing flashlights and in headlights, which some of your children may want to find out about.

A health note. Why should a mirror *never* be used to reflect sunlight into someone's eyes? Consult your school nurse or optician for the reasons this should not be done.

(Text page 34)

Reviewing the Concept

Before You Go On. 1. a 2. b 3. b 4. b

Using What You Know. A light-colored paint would reflect plenty of light in the kitchen. A darker-colored paint in the living room would absorb some light, and make it less bright. A rough finish would diffuse light and make it "softer."

(Text pages 35–38)

SUBCONCEPT

Light and sound are different forms of energy.

Section 2: LIGHT AND SOUND

Children observe that light and sound behave alike in some ways but do not behave alike in others.

Introducing the Concept

Equipment and Materials

- . . . pencil
- . . . hidden ruler
- . . . desk

Light and sound are fundamentally different forms of energy, although they do appear to behave alike in some ways. Both light and sound can be reflected, bouncing back from a surface; both can be absorbed, sinking into a surface. Both can travel through air. How can the children be started thinking about the differences between light and sound? You might tap a pencil on the desk where it can be seen by everyone. If you ask, "What am I doing?" the obvious answer will be that you are tapping a pencil. Now move the pencil out of sight behind the desk. Drop it (noiselessly) in an open drawer and pick up a ruler which you have in readiness there. Make the same tapping sound with the ruler. If you repeat your question, someone may say that you are tapping with the pencil, in which case you can produce the ruler. If some cunning child refuses to say what you are tapping with, you can produce the ruler anyway and congratulate the child on his shrewdness. In either case

Processes emphasized

Observation
Analysis of observations
Investigation (with design of experimental models)
Hypothesizing
Theorizing

pared. Is the print actually larger? (No—one can look at the page behind the jar and see that it is unchanged.) Why does it look larger, then? Something must be happening to the light that reaches the eye.

What happens to light when it passes through glass or water?

Read Section 3 up to **Purpose of a Lens,** and do the investigation on text page 39.

A convex lens bends light to a focus.

Equipment and Materials

See text page 39; also the Teacher's Manual for *Classroom Laboratory 4.*

Developing the Concept

The investigation. The larger the lens, the more positive the results will be, of course. Probably most of the children will already know that the small, very bright spot formed by the lens is hot. But why? The light energy from the Sun is changed into heat energy as it strikes the paper. This happens without a lens, however. The sunlight striking our skin turns to heat energy that we can feel. What does the lens do to produce so much heat energy that the paper chars? By moving the piece of cardboard back and forth between the lens and the spot, the children can observe that the light entering the lens is brought to a point on the other side. The lens makes a cone of light. It collects light energy from a large area (the area of the lens), and concentrates all this light energy in a small area (the area of the spot). The spot is hot because a lot of light energy is changed to heat energy there. Chalk dust from an eraser may be used to show the shape of the cone of light.

Now the question is, having seen these things, what does the lens do to the light? You may want the class to discuss this before going on.

You may want to draw on the chalkboard what happens to light passing through the convex lens, drawing one ray of light at a time and asking the children where each ray should go. This will make it clear that the rays are bent as they pass through the lens and focus at one point. (Notice that the rays are bent a little on entering the glass, and bent a little more on leaving the glass. This point is taken up later.)

When the convex lens in your eye focuses light on the retina, what happens? Show how the convex lens can form an image of a bright object (such as an electric lamp or a window) on a piece of white paper. The lens in the eye forms an image on the retina in the same way.

Light may be bent as it enters or leaves water.

Equipment and Materials

. . . slide projector
. . . cardboard slide
. . . aquarium or deep glass dish

More bending of light. The children may want to try sending a beam of light into water for themselves, of course. A slide projector can provide a strong, narrow beam of light if a piece of cardboard with a small hole punched through it is used in place of a slide. As the photograph on page 41 shows, it can be observed that the beam of light is bent as it enters the water; within the water the light travels in a straight line and is reflected as usual; but as it leaves the water the light is bent again. If the beam of light can be moved about, the investigators may discover that the light is bent only if it hits the water at a slant. When the beam hits the water at right angles, no bending takes place; the light goes straight through. The same sort of bending happens as light enters and leaves the convex lens.

Extending the Concept

When light bends. When light bounces, we say it is reflected; when it is bent, we say light is *refracted.* To extend the concept of refraction, this small group activity may be used instead of a demonstration. Each team or group of children will require the materials listed in the margin. The tumbler should be about three quarters full of water, with a little chalk dust or milk added. A hole about the diameter of a pencil is made in the black paper or cardboard. If the cardboard is laid over the mouth of the tumbler and the flashlight is pointed at the hole, the beam of light through the hole can be observed bending as it strikes the water at a slant. (This should be done in a darkened area.) What happens when the beam enters the water at right angles? (No refraction.) What happens as the beam enters the water at more and more of a slant? (The refraction increases, up to a certain point. Then the beam is reflected from the surface of the water.)

Equipment and Materials

- . . . tumbler
- . . . flashlight
- . . . black paper or opaque cardboard
- . . . chalk dust or milk

Coin in saucer. To emphasize how light is bent as it passes from the coin in the water to the eye (text page 42), sight along a ruler at a coin in a saucer of water. Then hold the ruler steady as you slide a pencil down the ruler towards the coin. If you can explain why you miss the coin, you can probably explain why a person trying to spear a fish from above the surface of the water should aim below the fish.

Equipment and Materials

- . . . saucer
- . . . coin
- . . . ruler
- . . . pencil

(*Text pages 42–43*)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. a

Using What You Know. If the convex lens is held at the right distance between a light bulb, say, and the screen, an image of the bulb is focused on the screen. If the lens is removed, light from the bulb reaches the screen—but no image is formed. If you had no lens in your eye, you would see light, but no image.

Section 4: ONE WAY TO MAKE LIGHT: A CANDLE

(*Text pages 43–48*)

SUBCONCEPT
Light energy may be released by a chemical change.

Children gain understanding of light as a form of energy released by chemical change.

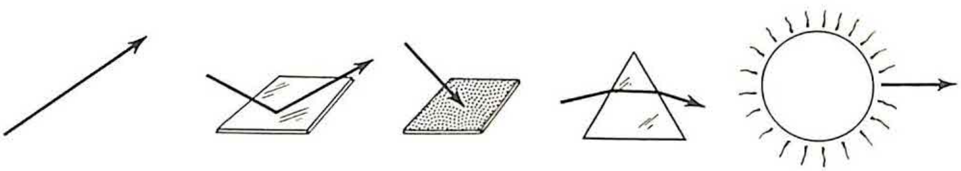
Introducing the Concept

Each of the simple diagrams on page T-28 suggests something that we have found out about the behavior of light. (In a, light travels in straight lines; in b, light can be reflected; in c, light can be absorbed; in d, light can be bent; in e, light can travel through space.) You may want to put them on the chalkboard, along with this question:

What have we learned about light, so far?

After these characteristics have been identified, it might be suggested that there is one important thing about light that has not been discussed:

What makes light?



As soon as a variety of answers has been offered, pupils read up to **Molecules and Light** and prepare to do the investigation on page 45.

Developing the Concept

The light energy of a candle comes from paraffin.

Processes emphasized

Observation
Analysis of observations
Hypothesizing
Investigation (with design of experimental devices)
Theorizing

Equipment and Materials

See text page 45; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. A thin candle is better than a thick one for this investigation; it will burn down more quickly from mark to mark. (Make sure that you are permitted to use an open flame in the classroom and take proper precautions.) If the candle burns steadily, about the same time will elapse from mark to mark. What we observe, then, is that the *disappearance* of a certain amount of paraffin coincides with the *appearance* of a certain amount of light—and we infer that there is a connection!

How does a candle work? The children will surely enjoy looking for answers to this question. Notice the melted paraffin around the burning wick. The solid paraffin in the candle is turned to liquid by the heat of the flame. What happens to this liquid? Dip one end of a strip of paper toweling into water; you can see the water rise through the paper. The liquid paraffin rises through the wick in the same way. As it rises in the wick, it is heated by the flame and the liquid paraffin turns to gas. It is this gas that burns. To show that this is so, blow out the candle flame and at the same time lower a lighted match to the smoking wick. The wick will light before the match touches it, as the gas from the wick catches fire. (The warm wick continues to form gas for a little while.) For more interesting investigations with a burning candle, see *A Sourcebook for Elementary Science,* pages 274–75.

An additional question that may intrigue some of the children is, what happens to the wick? (As it burns, it turns to tiny bits of ash which go off into the air.)

The light energy of a candle is produced by chemical change.

Molecules and light. As the paraffin burns, the molecules of which it is made are changed into different molecules—and light and heat are given off as these molecules change. The new molecules (what sort they are is told later on) are scattered in the air above the candle, by the action of the flame. You can make this action much more strikingly visible if the candle is placed a foot or two in front of a screen or wall illuminated by the bright light from a slide projector. Not only the shadow of the candle will be seen, but the shadow of the stream of gases being poured upward by the flame will be visible, as the new molecules are scattered in the air.

Safety in the use of matches and flames should be continually emphasized. Use a small can of sand to collect used matches. Investigations involving heat or combustion should be conducted on metal trays or asbestos sheeting. Set your children a good example!

What the changing molecules do. We all have a general idea of what the word *energy* means; scientists have a very specific idea. They define energy as the ability to do *work.* Scientists have a strict idea of what work is, too; they say that work is done when a force moves through a distance. But these strict definitions of work and energy are not absolutely necessary at this point, so they are not developed. The general ideas that go with work and energy will serve. Plan the investigation (page 47).

Energy is released during a molecular change.

The investigation. The candle used should be short enough so that its flame is well below the top of the jar placed over it. By sealing the two jars, after the flame has gone out, you trap the new molecules that the burning has made in the jars. Shaking the jars mixes the gases and the limewater in the jars, so that the reaction of the limewater is more marked. Before shaking, however, notice the drops of moisture that have collected on the glass above the flame. They are drops of water. Water molecules are formed in the flame.

Carbon dioxide and water are products of burning.

Equipment and Materials

See text page 47; also the Teacher's Manual for *Classroom Laboratory 4.*

When the limewater turns a milky color, carbon dioxide molecules have entered the limewater. Carbon dioxide, as well as water, is a product of the burning candle.

The chemical change of a candle. In the burning candle, molecules of paraffin change to molecules of water and molecules of carbon dioxide. As this chemical change takes place, light and heat are given off. If some well-informed child says something about water molecules being made up of hydrogen and oxygen—or carbon dioxide molecules being made up of carbon and oxygen—it can be pointed out that paraffin is made up of carbon and hydrogen. What about the oxygen? It comes from the air around the flame.

Chemical energy can become light energy.

But the important idea is that light can be made with chemical energy.

Extending the Concept

Do other light-producing substances go through chemical changes like those in a burning candle? Do other burning substances produce carbon dioxide and water? Use a bottle cap as a base for burning matchwood splinters. Set the cap afloat in clear limewater in a pan or dish, and cover it when lit with an inverted clean jar. You may have to slosh the limewater around in the jar, holding jar and dish together tightly, to mix it with the products of burning. Let the jar cool first! Try burning a small piece of paper also. It will be found that carbon dioxide and water are produced. Many experiments have shown that this is true for all burning substances.

Equipment and Materials

- . . . bottle cap
- . . . glass jar
- . . . dish
- . . . limewater
- . . . matchwood splinters

Reviewing the Concept

(Text page 48)

Before You Go On. 1. b 2. b 3. a 4. a

(Text pages 48–52)

SUBCONCEPT

Light energy behaves sometimes as waves, sometimes as particles.

Section 5: HOW LIGHT TRAVELS

Children learn that scientists have developed two theories about how light travels.

Processes emphasized

Library research
Observation
Analysis of observations
Measurement
Investigation (with development of models)
Hypothesizing
Theorizing
Prediction

Introducing the Concept

To approach this question of *how* light travels, you may want to pose this question:

What is the fastest thing you know?

Sound travels 1,000 feet per second, approximately (Unit One), or about 760 miles per hour. Airline jet planes can cruise at about 600 miles per hour. Military jet planes can move at 3 or 4 times the speed of sound. The giant rockets that put a space capsule into orbit around the Earth reach a speed of about 18,000 miles per hour. (Information on speed records on land, water, and in the air, may be found in books such as the *World Almanac.*) But the fastest thing we know is light, which travels at 186,000 miles *per second*. How much is that in miles per hour? If you point a flashlight at the sky on a clear night, and switch it on, how far away from you is the front of the beam in one second? Switching off the flashlight chops off the tail end of the beam, but the rest keeps on going out into space.

Light travels—and travels fast. But:

How does light travel?

Read up to **How the Light Is Stopped**, and do the investigation, which gives an important clue to the nature of light.

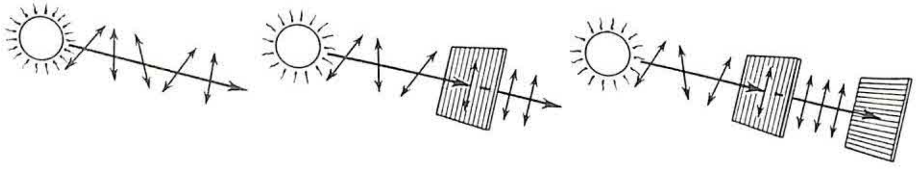
Light can be polarized by certain materials.

Equipment and Materials

See text page 49; also the Teacher's Manual for *Classroom Laboratory 4*.

Developing the Concept

The investigation. Pieces of Polaroid plastic or glass may be obtained from a scientific supply company, or may be available from your local optician. Some hobby shops carry Polaroid material along with other science materials for boys and girls. Or an old pair of Polaroid sunglasses may be cut apart. The fact that two pieces of Polaroid (at a certain angle) can stop a beam of light, although neither piece can do so alone, can be explained in this way: Assume that light travels as waves, waves that vibrate in several planes at once. Light that passes through a single piece of Polaroid is vibrating in just one plane. When another piece of Polaroid is placed in this beam, at the right angle, the light is cut off completely. Only waves would be stopped like this; particles would pass through. So we take it that this behavior of light means that light is made up of waves, not particles.



The behavior of polarized light is explained by a wave model.

Equipment and Materials

. . . clothesline
. . . two cardboard cartons

How the light is stopped. You may want to do a demonstration similar to that shown on text pages 50 and 51. Tie one end of about 15 feet or so of light clothesline or sashcord to a table leg. By moving the free end of the rope up and down quickly, you can make waves that travel along the rope. (See the investigation on page 13 of Unit One.) Pass the rope through a narrow slot cut in a cardboard carton. Waves in one plane only can pass through the slot. Pass the rope through a second slot like the first. Do the waves in the rope reach the table leg if one slot is vertical and the other horizontal? Could particles go through the slots? What happens to the rope waves as one slot is gradually turned across the other? What happens with the Polaroid pieces as one is gradually turned? Does the model behave as the Polaroid does?

Light that has been made to vibrate in only one plane—by passing through a piece of Polaroid, for example—is said to be polarized.

It might be thought that light must be one thing or the other, either waves or particles, and that two theories cannot occupy the same space at the same time, so to speak. But what this means is that we don't know any model that behaves like both a wave and a particle. That does not mean that it can't happen.

Extending the Concept

Night driving and glare. Have you ever heard a driver complain of the blinding glare from the headlights of an oncoming car? Could you use what you know about polarized light to invent a solution to this problem? If auto headlights were polarized in one direction, what would have to be done to auto windshields?

The speed of light. Find out what you can about the Danish scientist Ole Roemer, who was the first to estimate the speed of light accurately. He suggested that the fact that the moons of Jupiter sometimes appeared ahead of schedule and sometimes behind schedule might be due to light taking different times to travel the changing distance between the Earth and Jupiter.

(*Text pages 51–52*)

Reviewing the Concept

Before You Go On. 1. a 2. a 3. a

Using What You Know. 1. Two sheets of polarized glass or plastic would do the job, if one were set at right angles to the other. 2. Light waves can travel through space; sound waves cannot. Light waves cannot travel through most solids and liquids; sound waves can. Light waves vibrate in one direction; sound waves vibrate in many directions.

(*Text pages 52–54*)

CONCEPTUAL SCHEME
When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT
A loss or gain of energy affects molecular motion.

Has your idea of light changed?
How did we find out about light?

What is needed to make light?

How do we know that light is a form of energy?

Equipment and Materials
- . . . radiometer
- . . . exposure meter

Section 6: THE MAIN CONCEPT: HOW LIGHT BEHAVES

Children form a concept of light as energy which may be transformed.

CONCEPT SUMMARY

What new things have the children learned about light? How has their idea of light changed from what it was? You may want to discuss these questions with the class, as an introduction to the Section. In other words: How has the *concept* of light changed? This is what we are really asking, and in the New View which follows (pages 55–59) the word *concept* is formally introduced and developed.

Note that what the children have found out about this mysterious form of energy, light, has been found out by putting light through some of its paces, so to speak—by observing how it behaves under different circumstances and by thinking about what the behavior may mean, as well. For example, it was *observed* that light can be reflected and *thought* that light is like sound in this respect. The behavior of light as it passed through polarizing material was observed; thinking about what this observation might mean suggested to scientists—and to us—something about the nature of light.

To make light, energy is required. What provides the energy for the light that goes on when the wall switch is flipped? Electricity, of course; and, if you wish, this electric energy can be traced back to the chemical energy stored in coal, for example. It takes energy to make light, and that energy (whatever kind it is) is changed into light energy. Then that light energy may be changed to some other form of energy.

Energy is the ability to do work. If light is a form of energy, then light must be able to do work. Can light energy be put to work? Children sometimes bring in from hobby stores or toy stores the interesting device called a radiometer. It has four vanes mounted so that they can move inside a glass bulb. The bulb has very little air in it, and each vane has one black and one shiny side. When light shines on the vanes, they spin around. This device, then, puts light energy to work moving the vanes around. After it has been shown that it is light (not some other form of energy) that makes the vanes move, the question is, how? What do you observe about the vanes? Each vane has a shiny and a black side and moves with the shiny side in front. (This fact kills the hypothesis that light reflected from the shiny side drives the vane around.) What happens is this: The black side absorbs light energy; its molecules move about more rapidly than those on the shiny side, and they bump harder against the few air molecules in the bulb than those on the shiny side. So the molecules on the black side, kicking harder than those on the shiny side, push the vanes around when light strikes them. The light energy is changed to heat energy, which makes the molecules move faster; in turn, the moving molecules produce mechanical energy, which moves the vanes.

Another fairly direct way of observing the work that light energy can do is to observe its effect on a photographer's light meter. How does light energy make the pointer move? The light energy falls on a kind of metal, selenium, which can change the light energy into electric energy. The tiny electric current goes to a very sensitive electric motor, which makes the pointer move. Then, of course, we see around us green plants, which are able to change light energy into energy that they need for growth.

Does energy disappear?

You may wish to emphasize the concept that energy can be changed from one form to another by tracing some energy changes. To lift a pencil, for instance, takes mechanical energy, which comes from the muscles. The muscles change chemical energy from the food you eat into mechanical energy. Where does the chemical energy in food come from? Eventually from the light energy of the Sun, of course. Then, to go to the other end of this energy chain, if you drop the pencil you have lifted, some of the energy you have given the pencil changes into sound energy, as the pencil hits the table. This sound energy travels through the air . . . and so on. A flashlight changes the chemical energy in the battery to electric energy to light energy. The chemical energy in gas changes to heat and light energy as the gas burns; some of the heat energy becomes chemical energy again as it makes changes in the food cooked. Whatever the changes that energy undergoes, it does not disappear. It always turns up in some form or other.

Scientists used to believe that energy always remained energy, whatever form it took—and that the amount of energy in the universe never changed. Now they know that under certain conditions energy may change into matter; under certain conditions, matter may change into energy. Even so, in a sense the energy has not disappeared. It has assumed still another form, matter, and may return to the form of energy again. But because of the discovery that energy can change to matter and matter to energy, scientists have amended the concept that the amount of energy in the universe does not change: they say that the amount of matter and energy in the universe does not change.

FIXING THE MAIN CONCEPTS

(Text pages 53–54)

Testing Yourself. **1.** a **2.** a **3.** b **4.** b **5.** a **6.** b **7.** a **8.** b **9.** b **10.** a

A NEW VIEW OF SOUND AND LIGHT

(*Text pages 55–59*)

CONCEPT RELATIONSHIPS
Both light and sound are forms of energy.

This is the first of four "New View" sections that follow Units Two, Four, Six, and Eight. What is a "New View"? It is not a review or summary. It is rather a somewhat more informal and free development of some aspect of concepts in the preceding units. It may be the bringing together and interrelating of certain ideas from preceding units or the introduction of a new idea that will be useful in units to come. In this first New View the idea of a concept is introduced.

TEACHING SUGGESTIONS

The Nature of a Concept

You may wish to have the children examine the dogs in the illustration before reading the text. Is there a dog there that any child has not seen before? Is there a dog that any child cannot identify? If so, then the question is this: If you have never seen it before, if you don't know what it is, how do you know that it is a *dog?* The children may begin to enumerate the characteristic features of dogs in general; that is, to describe the *concept* of a dog. We are able to identify as a dog an animal we have never seen before because we have a concept of a dog. What is a concept?

It may be interesting and helpful to look up the definition of the word *concept* in your dictionary and discuss it. What other concepts do we have in our minds besides concepts of a dog and a ball? The list is practically endless, of course. You may want to place in view some object that the children have not seen before—an odd-colored marble for instance, a book, a plant, or whatever. If they have never seen it before, how do they know that it is a marble, a book, a plant? They know because they have in their minds concepts of these things, of course. What makes up the concept of a marble? Its roundness, its size, its material, its weight. A cube of glass of the same size and color as a marble is not identified as a marble. Why? Its shape does not fit the concept of a marble. You can soon show that we carry a great many concepts about in our minds. Why do we do so? Let the children explore the question and then read on in the New View.

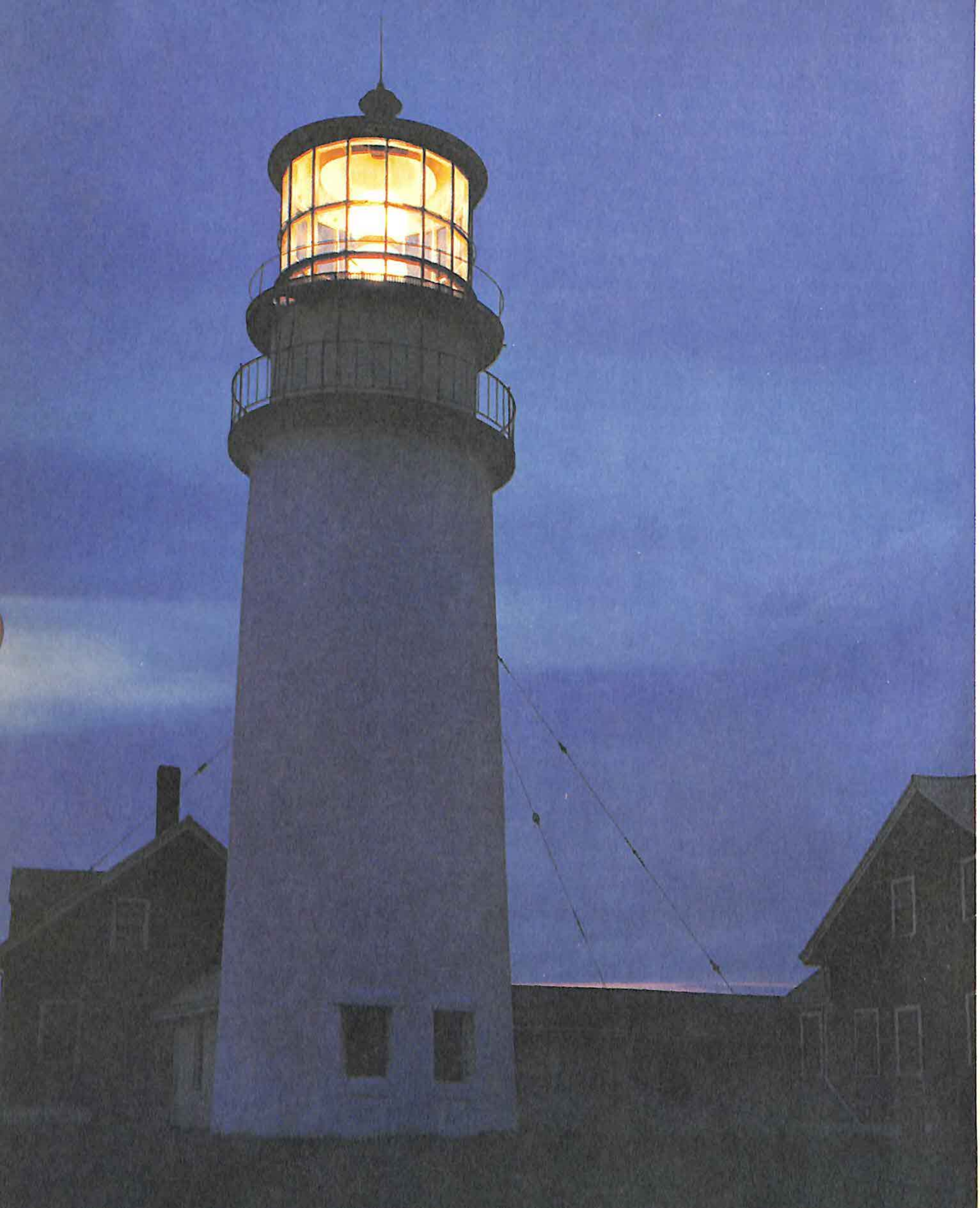
Functions of a Concept

A concept makes things easier to carry in your mind and allows you to classify things you have never seen before. A concept is more than a kind of convenient filing system, however. A concept has a store of information attached to it, as a rule, and that information can be applied at once. For example, if you encounter a strange animal which you decide fits the concept of a skunk, you recall some information connected with that concept and perhaps withdraw quietly. Thus a concept brings order to a potentially disorderly situation.

Use and Relationship of Concepts

As one result of many experiments and much thought, scientists decided that light is a form of energy. What a powerful idea this is! For it applies to light the great store of information—facts, principles, concepts—that scientists have built up about energy. The likenesses and the differences between light energy, sound energy, heat energy, and so forth become clearer. The concept of energy is enriched, too, by the example of light. Since energy can be changed from one form to another, and since light is a form of energy, we know that when light disappears we must look for the appearance of some other form of energy. When light is absorbed by a dark surface, for instance, we should look for the appearance of some other form of energy. We find that the temperature of the dark surface is raised; the light energy has become heat energy.

The concept of energy has been a most potent one in science. It has brought order across many different fields.



UNIT TWO

THE BOUNCE OF LIGHT

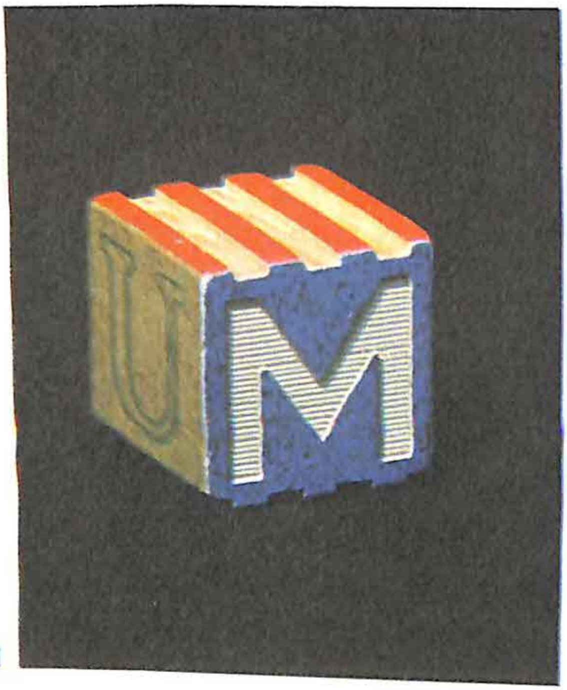
Light.

You have only to close your eyes to know how important light is to you.

What is light?

You cannot taste it. You cannot smell it or touch it. You cannot hear it. You can only see it.

How can we possibly learn anything about such strange stuff? Turn the page and see.



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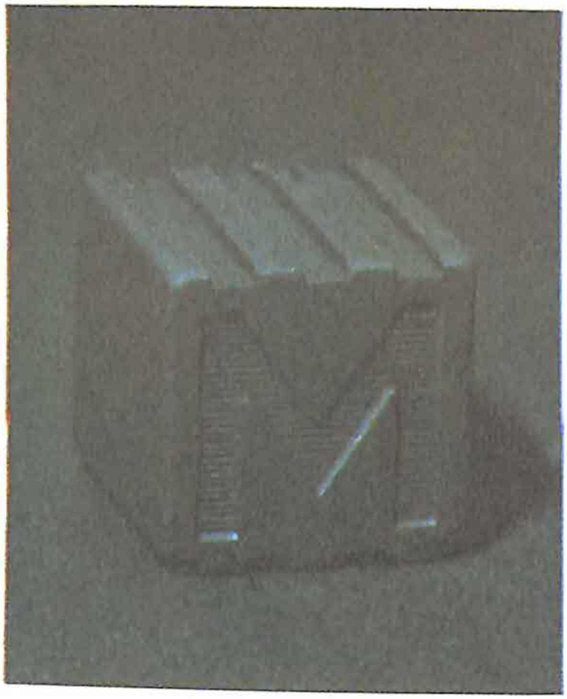

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1. When Do We See?

Have you ever walked along a road on a dark night? All of a sudden an automobile comes around a corner and you see the road lighted up in front of you. Why was it you saw telephone poles, trees, houses—everything along the roadside?

Let's look at another common example.

Have you ever used a flashlight to look for something in the dark? You move the ray of light around, and at last it strikes the thing you are looking for. "I see it," you say. When you want to see something, you shine a light on it. ■ See the picture marked with a square. But is just shining a light on something always enough to see it?

Here is the same figure, and the same light is shining on it. ● The figure has been painted black. Even though the light is shining on the figure, the figure can hardly be seen.

Just shining a light on something you want to see is not enough, then. What else is needed? Try the investigation on the opposite page. You will find some evidence there.

When Light Hits

When the mirror is held in the light in front of the dark book, the page lights up brightly. Why? Because the

AN INVESTIGATION into How Light Behaves

Needed: a book, a mirror, a light, a piece of black paper, a piece of white paper

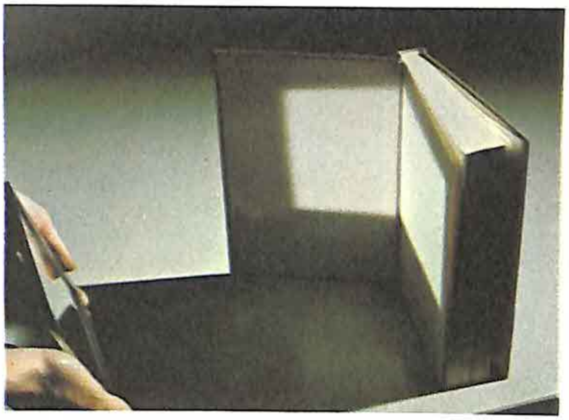
Open to a clean white page inside the front or back cover of the book. Prop the book against the light so that the open page is in a shadow, like this. ■ The darker the shadow, the better.

Hold the mirror in front of the book, in the light. What happens to the dark page? ●

Hold the piece of white paper in the light in front of the book. What happens to the dark page? ▲

Now hold the piece of black paper in the light in front of the book. What happens to the dark page now? ◆

How do you account for what happens? What statements can you make about how light behaves?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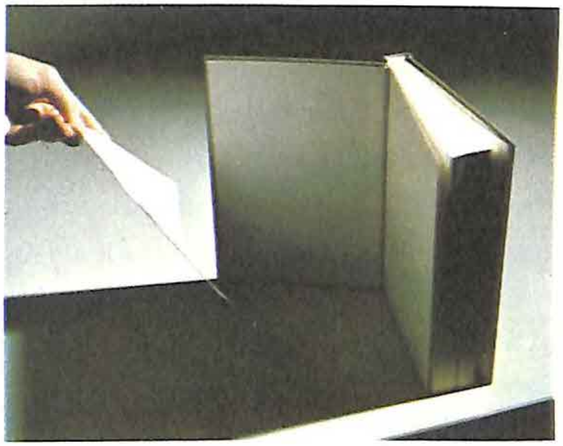
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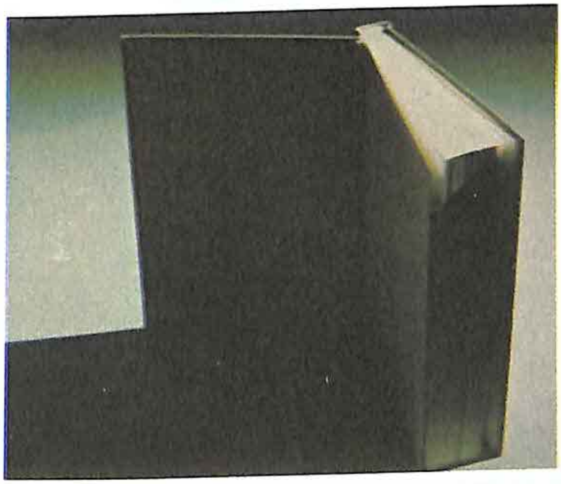

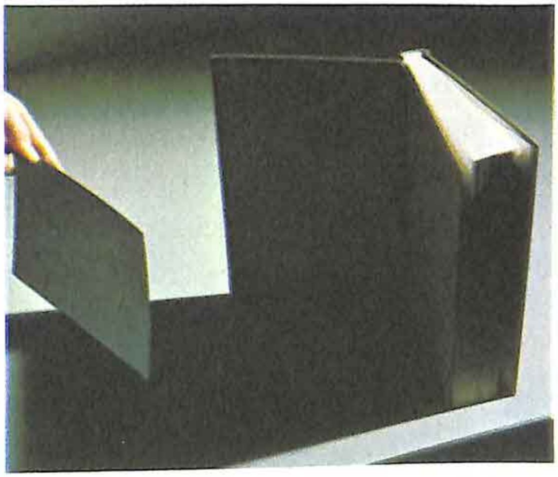
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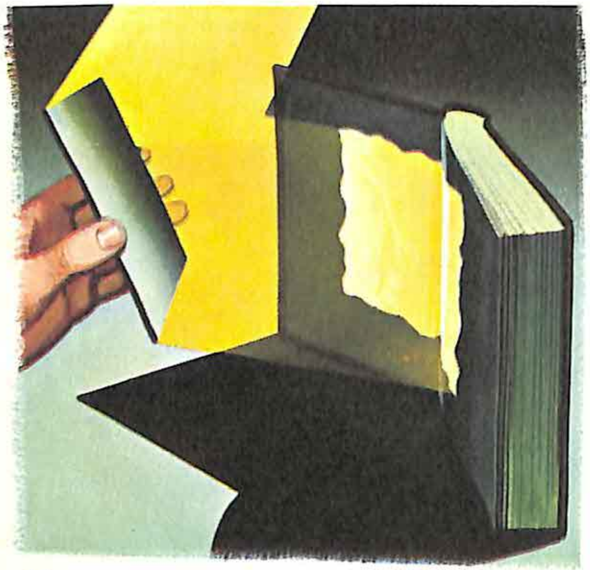

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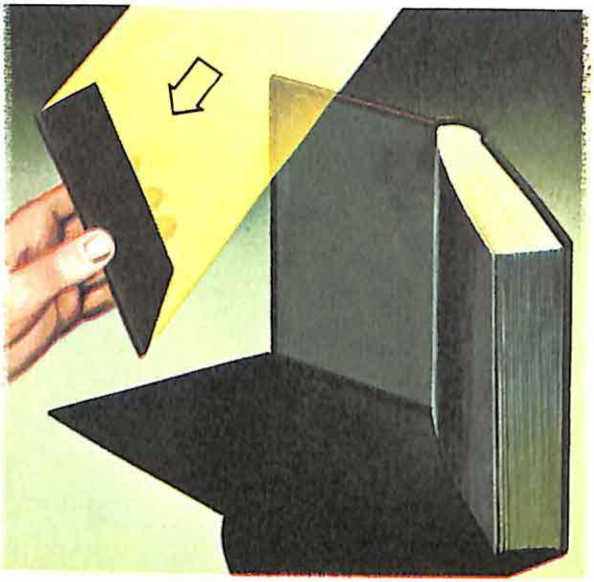

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light that hits the mirror bounces off *and hits the book.* ■

You knew this long ago, to be sure. Haven't you bounced sunlight off a mirror to make a spot of light dash around a room? That spot showed something about light. It showed that *light bounces.*

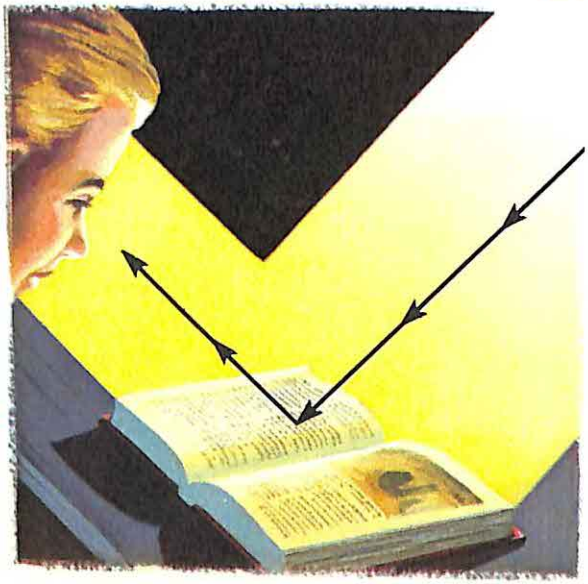
What happens when light hits the white paper? When the paper is held in the light in front of the book, the book lights up. Light bounces from the white paper to the book.

When light bounces, it is said to be **reflected.** Light was reflected from the paper to the book. Light was reflected from the mirror to the book.

When the black paper is held in front of the book, almost no light bounces from it. ● Black paper does not reflect light. Instead of bouncing, most of the light sinks into the black paper. The light is *absorbed.*

When light hits something, it may be either reflected or absorbed. Shine

▲



light from a flashlight on something. The light is reflected from it and bounces *back to your eye.*▲ You can see the object when light is reflected from it.

Mirror and Paper

You can see yourself in a mirror. Yet you cannot see yourself in a piece of white paper. Why not, if both paper and mirror reflect light? What makes the difference?

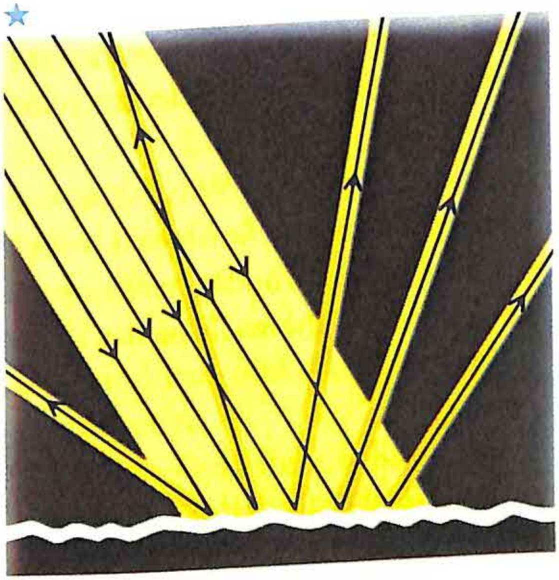
Have you ever looked at paper under a microscope? Even the smoothest looking paper has a rough and uneven surface. Here is a photograph of the paper of this book seen through a microscope.◆

◆

Because the surface of the paper is rough, light that strikes it is reflected in all directions.★ We say that the light is **diffused.**

The reflecting surface of a mirror is very smooth indeed. The smooth and even surface reflects light in an even, regular way.◈ The rays of light are

★



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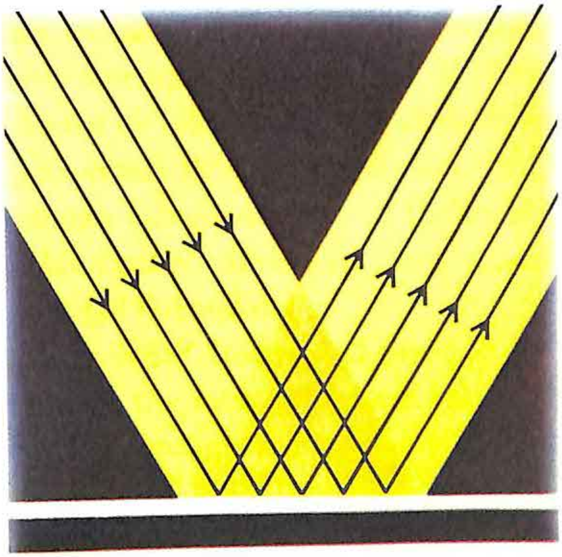


not mixed up, as they are when reflected from a piece of paper—or another rough surface. You can see yourself in a mirror because the reflected light is regular. You cannot see yourself in a piece of paper because the reflected light is diffused. That is, the light is scattered in all directions.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. When light hits a mirror or white paper, the light
   a. bounces b. sinks in
2. When light hits a piece of black paper, most of the light is
   a. reflected b. absorbed
3. White paper diffuses light because the paper is
   a. smooth b. rough
4. You can see this page because light from it is being reflected
   a. away from your eyes b. to your eyes

USING WHAT YOU KNOW You have to choose wall paint for two rooms. In the kitchen plenty of strong light is needed. In the living room soft light is needed.

What colors of paint would you choose? Why? You can also choose paints that will give a smooth finish or a rough finish. What kind of paint would you put on the walls of the kitchen? What kind would you put on the walls of the living room? Why?

ON YOUR OWN Does chalk dust absorb or reflect light? If your teacher permits, demonstrate this to your class.

2. Light and Sound

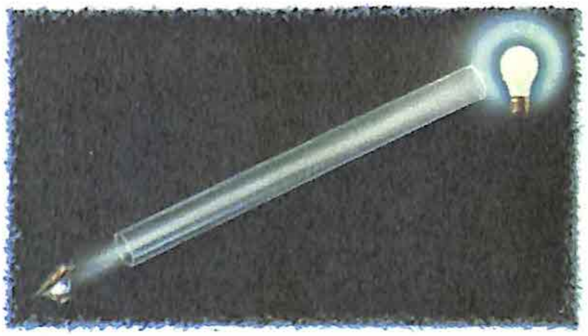
Most of the things we see, we see by reflected light. Light bounces from them to our eyes. Look around you. How many different things are reflecting light to your eyes now?

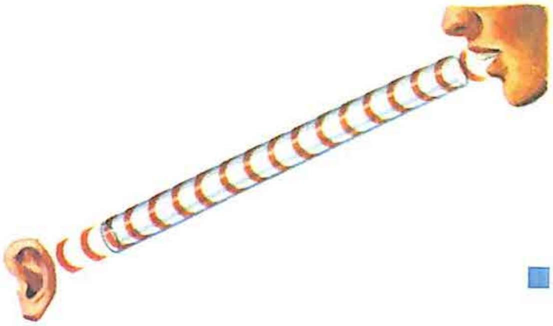
Yet there are some things that you do not see by reflected light. Some things make their own light. An electric light bulb makes its own light. A candle flame makes its own light. The television screen makes its own light. The Sun makes its own light. So do the other stars. (The Moon is seen by reflected light, as you probably know.)

Some things make their own light. Most things, however, are seen by reflected light.

Does the fact that light bounces remind you of sound? Sound bounces too. When we hear an echo, sound is being reflected and is bouncing back to our ears. Light and sound are alike in another way. Light can be absorbed instead of reflected. Sound can be absorbed too. When sound strikes a soft material, such as cloth, some of the sound may sink in, instead of being reflected.

Do sound and light behave alike in other ways? Let us observe another way that light behaves, and see.



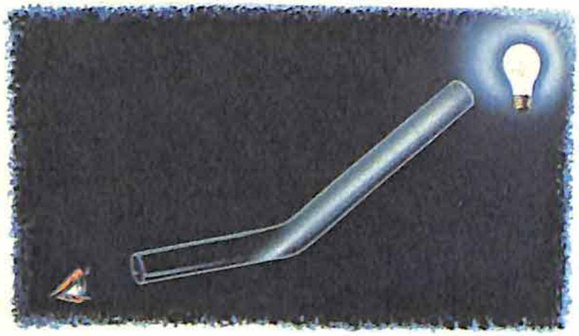


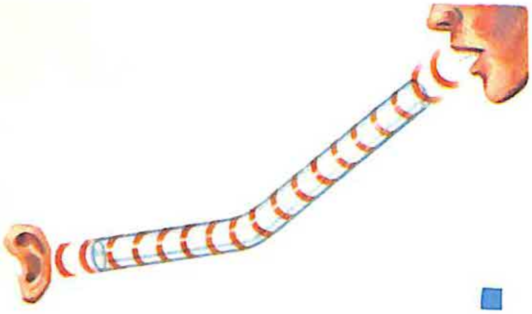
The Path of Light

A straight tube of cardboard or newspaper, 2 or 3 feet long, will help you to find out more about light.

Look through the tube. You can see out the other end, because light rays are traveling through the tube to your eye. ■ Put the end of the tube to your ear. If someone speaks softly into the tube, you can hear the sound. Both light and sound can travel through the tube.

Now stuff a crumpled piece of paper into the tube. Of course you cannot see through the tube any longer. You can still hear through it, however. Sound can get through the crumpled





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paper all right. Light does not. Here, then, is one difference between light and sound. Sound can pass through some things that light cannot get through.

There is another difference between light and sound that is shown by this simple tube. Of course you know that if you bend the tube enough, you will not be able to see through it. Have you ever thought what this tells you about light? You cannot see through a tube that is not straight, because *light travels in straight lines only*. ■

What about sound? If you put the end of the bent tube to your ear, you can still clearly hear sound through it. Sound is not stopped by the bend.

If a friend calls you from around a corner, you can *hear*. You cannot *see* your friend, though, because light travels in straight lines only. Sound travels in straight lines too. But sound can go around corners as well. ●

Where Light Can Travel

Light cannot travel around corners. Sound can. Sound can travel through substances that light cannot get through.

Yet light can travel where sound cannot. Light can travel through space where there are no molecules. Sound cannot. Light can travel through space from the Sun to the Earth, from the Sun to the Moon, from the Moon to the Earth. Light can travel through space from the stars to the Earth, and from the Earth to the Moon. Sound cannot.

Sound travels by molecules bumping each other, moving to and fro, passing along the push and pull of a vibrating object. Sound can travel through solids such as wood and iron, through liquids such as water, through gases such as air. Solids, liquids, and gases are all made up of molecules. For sound to travel, molecules are necessary. Where there are no molecules, or too few, sound cannot travel. Astronauts landing on the Moon cannot talk to each other as they do on Earth. There is no air on the Moon, so there are no molecules of air to carry sound. There are so few molecules in space that sound cannot travel at all.

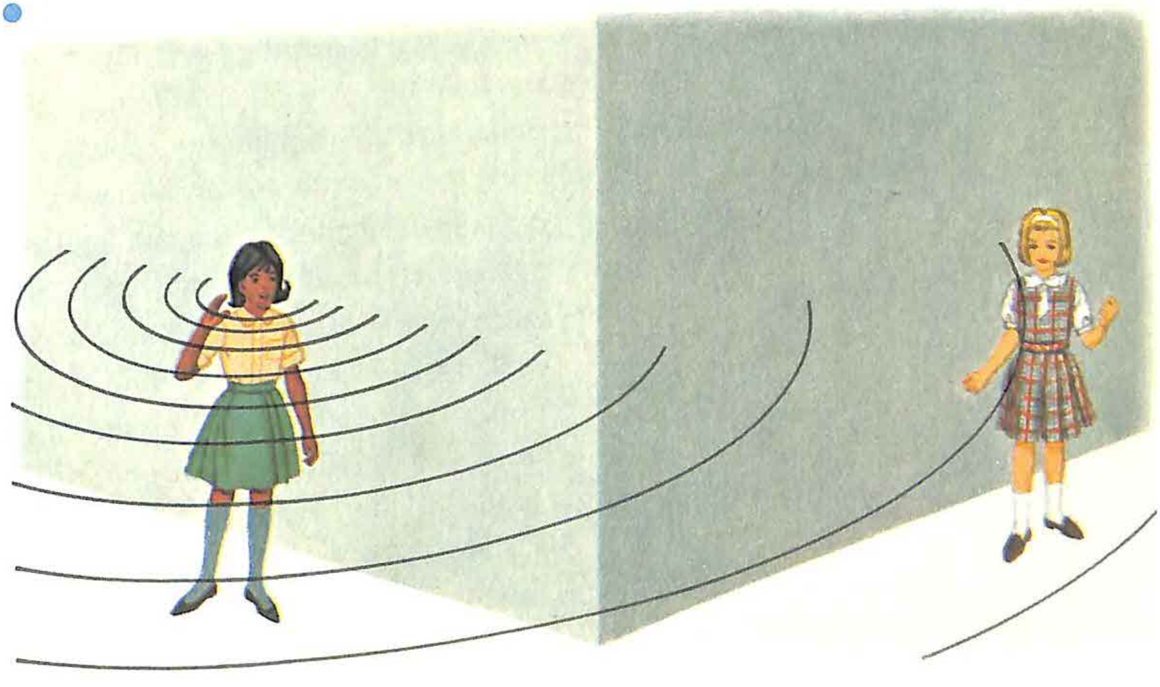
Molecules are necessary for sound to travel. Molecules are not necessary for light to travel, however. Light can travel where there are no molecules. Light can travel through space.

Light and sound behave alike in some ways, but they are not alike.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Sound and light are
   a. the same b. different

2. Sound and light are aimed at a thin wooden door. The one that gets through is
   a. sound b. light



3. Only one of these can travel through outer space. That one is

a. sound b. light

4. Molecules are necessary for one of these to travel. That one is

a. sound b. light

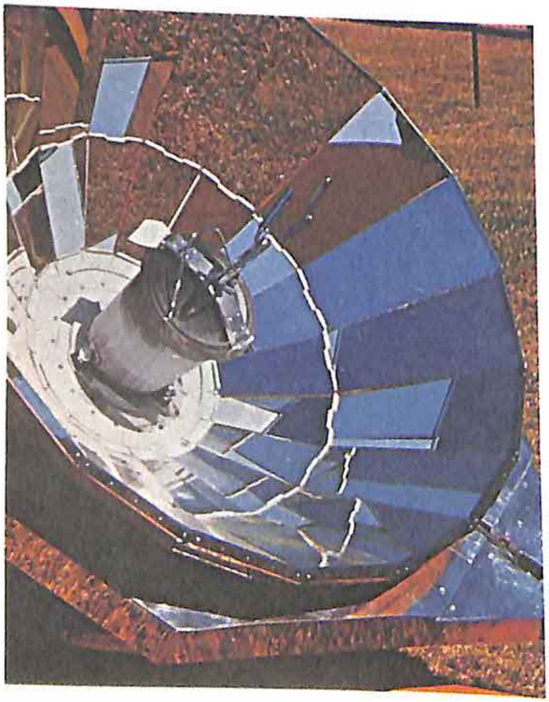
USING WHAT YOU KNOW

1. Explain how you would make a room soundproof.

2. How would you make a room lightproof? Why would your plan work?

ON YOUR OWN

Ask a builder for pieces of material used to cut down sound in a room. Take the material apart and see if you can explain how it works.



■

3. Bending Light

Heat goes with the Sun's light, you know. When you stay too long in the sunlight, the Sun's **energy** cooks your skin. You say you are sunburned, but it might be better to say sun-cooked.

Here is something that puts the Sun's energy to good use. ■ This sun cooker makes use of reflection. Light from the Sun is collected by the shiny surfaces and reflected to the container in the middle. Food can be cooked.

There is a way of collecting light that does not depend on reflection. Try it yourself in the investigation.

AN INVESTIGATION into Light through a Lens

Needed: a magnifying glass (convex lens), a pie tin or metal plate, a piece of paper, a piece of cardboard, sunlight

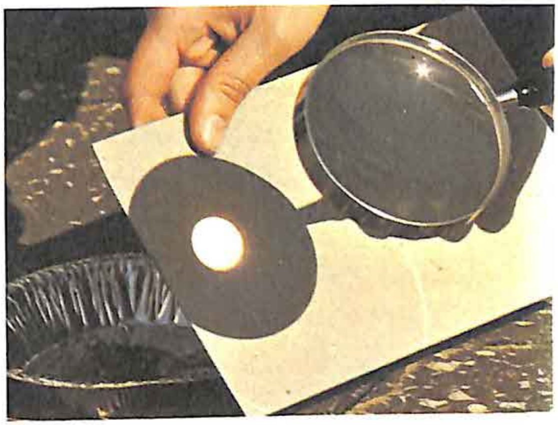
A lens that is thicker in the middle than at the edges, like a magnifying glass, is called a convex lens. Hold the convex lens between the paper and the Sun, and facing the Sun.

Move the lens back and forth between the Sun and the paper until a small and bright spot of light rests on the paper. Hold the lens in that position. What happens to the paper? ■ What does this show about the spot of light?

Keep the lens in the same position. Hold the piece of cardboard near the lens and then move it away from the lens toward the spot of light. What is the shape of the light coming through the lens? ● ▲

Make a drawing of what happens to the light that goes through the convex lens to the paper.

■



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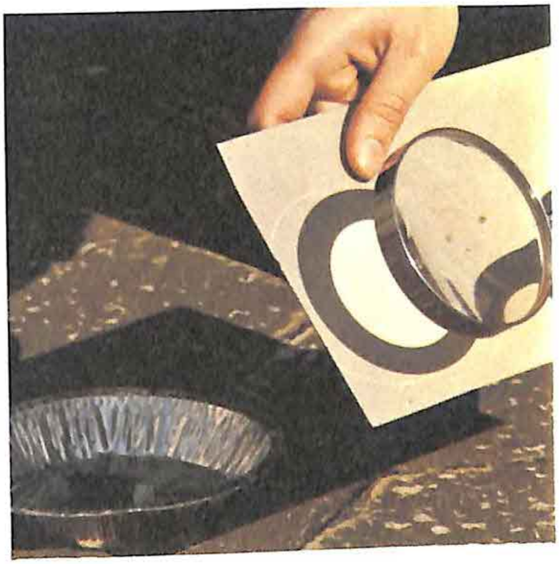

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Purpose of a Lens

You may have used a magnifying glass or convex lens before. But have you ever thought about what the **lens** shows about light?

What is the lens doing when it makes that very bright and hot spot of light? The lens collects light from a large area and aims it at a small area. ■ We say the lens **focuses** the light when it brings the light to a point. The heat where the light is focused may be great enough to scorch or burn paper.

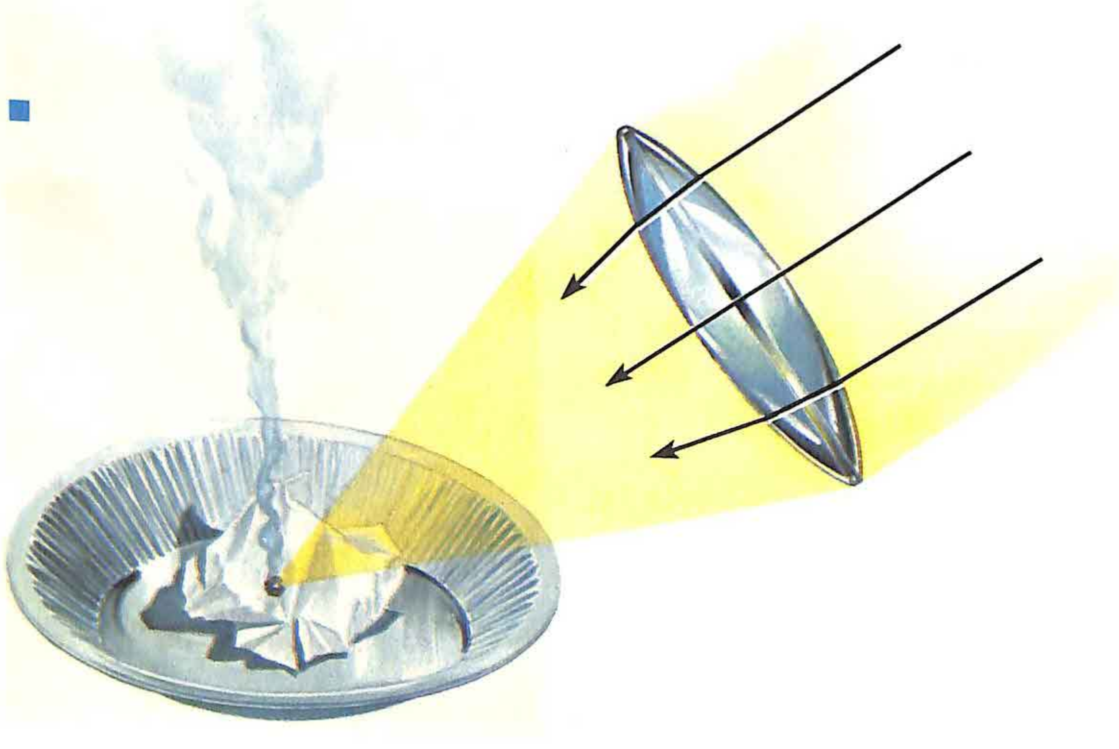
How does the lens focus light? The sun cooker focuses light by reflection. How does the lens do it? The lens *bends* the light. ■

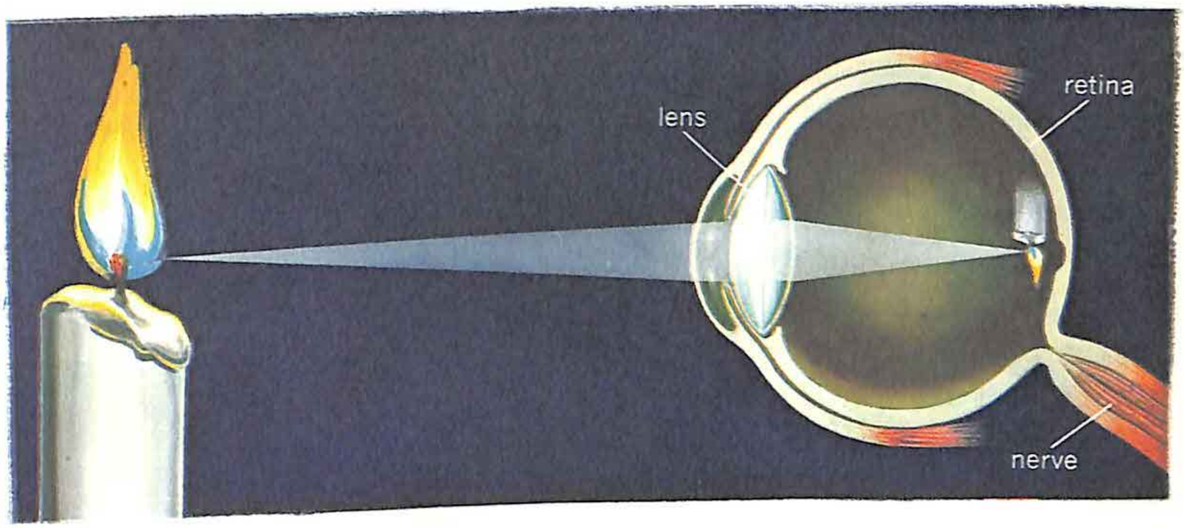
The light passing through the glass of the lens is bent, so that all of it meets at one place. Notice that the light that passes through the edge of the lens is bent the most. The light that passes near the center of the lens is bent only a little. The light at the center goes straight through.

What does the lens show us about light? It adds to our knowledge of light by showing us that *light can be bent.*

Do you know how the bending of light is important to you? Here is a

■





●

drawing of your eye.● Notice the convex lens. It focuses light on the back of the eye, the **retina** (RET·ih-nuh). When light from an object strikes your retina, you are able to see the object. Without a lens to bend the light entering your eye, you would not see clearly at all.

More Bending Light

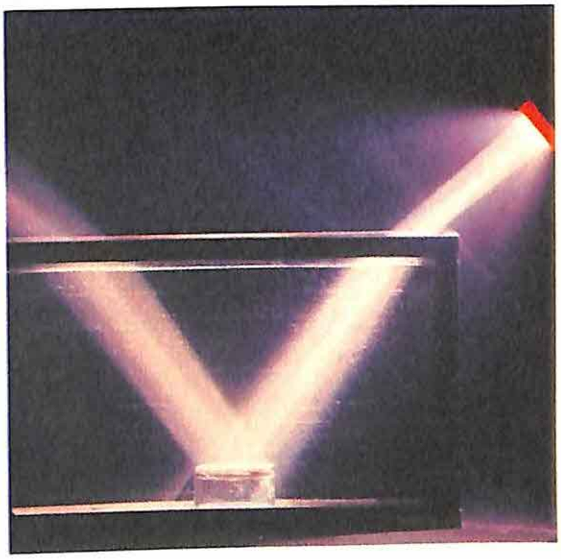
Here is an aquarium with some water in it. A few drops of milk have been put in the water to make it cloudy so that light passing through the water can be seen. A beam of light is aimed at the water. What happens to the beam of light as it enters the water?▲

A mirror has been laid at the bottom of the tank, under the water. What happens to the light when it strikes the mirror?

The mirror sends the beam of light up again, and out of the water. What happens to the light as it leaves the water?▲

Here is another example of bending light that you can easily try for yourself. Put a coin in an empty saucer. Then get down so that the edge of the

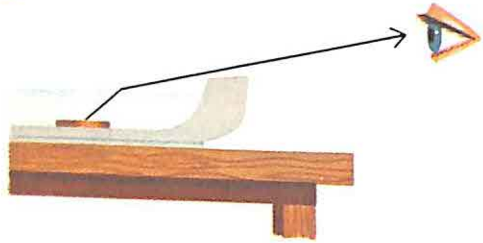
▲



saucer just hides the coin from your eyes. Pour in water, slowly and carefully. The coin will slowly appear above the rim of the saucer. ■ See if you can figure out how the light goes from the coin to your eye. Make a drawing and then compare it with the ray on page 41. Light can be bent, but it is bent in a special way.

The rays of light from the coin to your eye are bent over the edge of the saucer like this. ●

●



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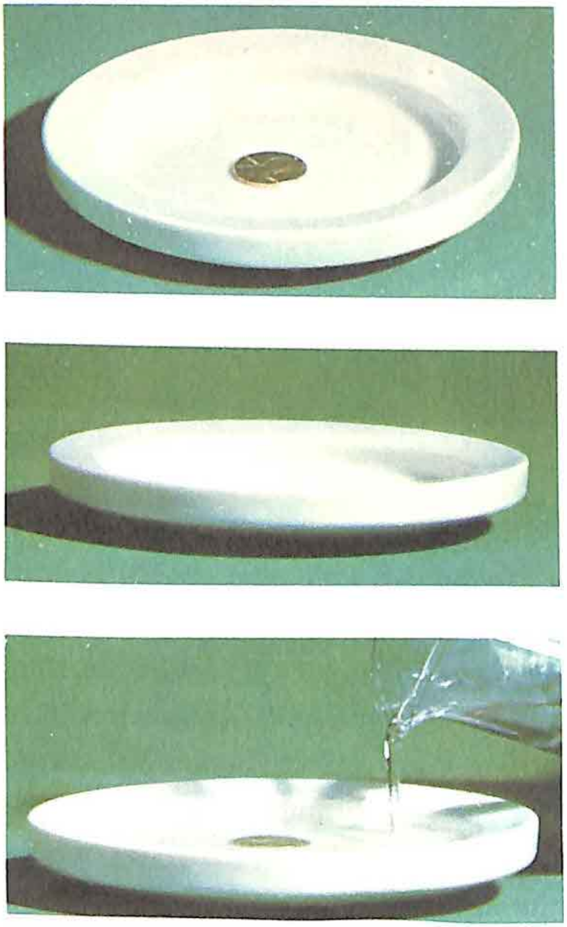


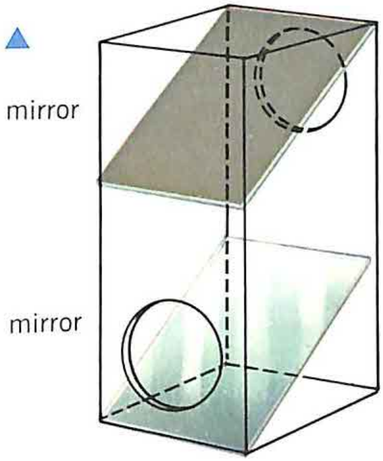
BEFORE YOU GO ON

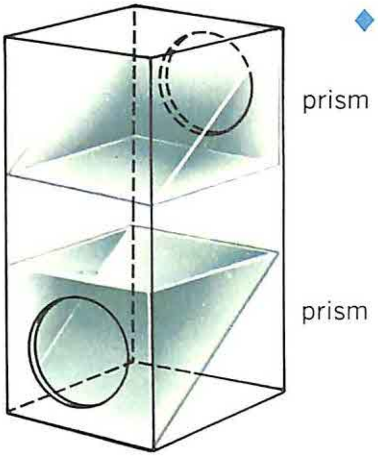
Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. When light is collected and brought to a point by a lens, we say the light is
   a. reflected b. focused
2. Light going through a convex lens
   a. is bent b. goes straight through
3. Light going through water
   a. may be bent b. must go straight through

USING WHAT YOU KNOW If you had no lens in your eye, would you see light at all? Demonstrate your answer with a convex lens and a cardboard screen.

ON YOUR OWN Explain how this periscope works.▲ Then see if you can explain how this one works.◆





4. One Way to Make Light: A Candle

Look at what we have found out about light by observing how light behaves, by reasoning, and by using knowledge that scientists have given us.

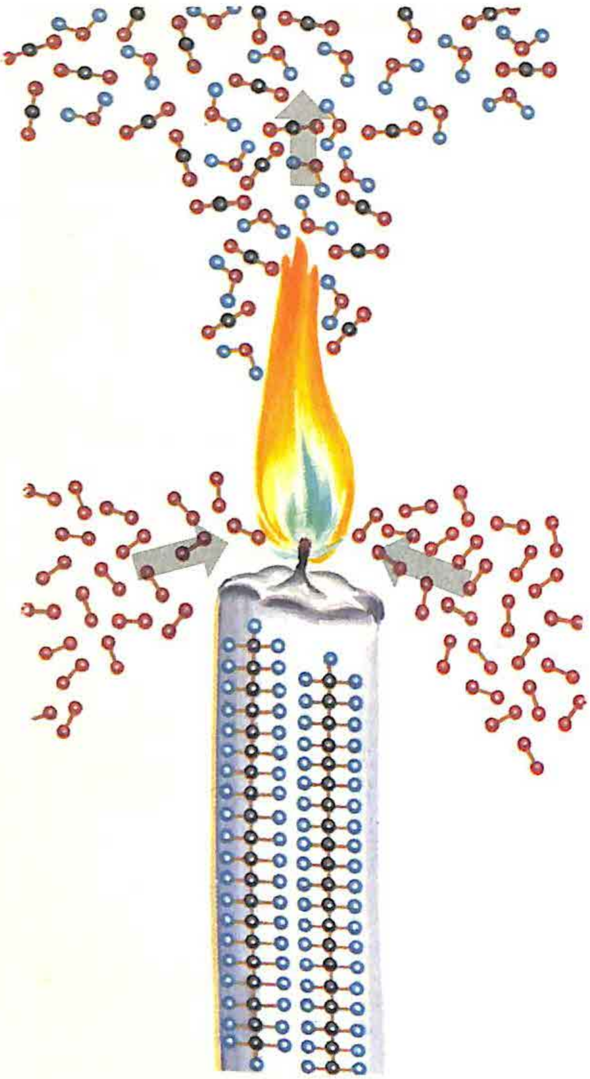
Light travels in straight lines.
Light can be reflected.
Light can be absorbed.
Light can be bent.
Light can travel through space.

We have been able to find out something about this strange stuff, light, after all—even though we cannot feel light, taste it, smell it, or hear it.

What makes light?

Let us make some light with an old-fashioned light maker, a candle. It can show us something about how light is made.

A burning candle makes light and heat. At the same time, while it is making light and heat, some of its paraffin (PAR·ah·fin) disappears. We



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know that when paraffin is gone, the candle stops burning. The candle depends on the paraffin for making light. Where did the paraffin go? Somehow, it seems the paraffin is turned into light. But how? See for yourself, by doing the investigation on the opposite page.

Molecules and Light

Like all matter, paraffin is made up of molecules. The molecules that make up paraffin get into the flame of a candle, through the wick. In the flame, the molecules that make up paraffin change into other molecules. As they change, the molecules give off light and heat.

As the candle burns, its molecules are changed into other molecules. These other molecules are then scattered into the air around the candle. The substance of the candle disappears, not because it has been destroyed, but because it cannot be seen. Its molecules are scattered far and wide in the air. ■

We call this kind of change a **chemical change.** Burning is a chemical change. Burn a piece of paper and it changes to a substance very different from what it was. It changes into a black or gray ashy substance. The molecules that made up the paper have been through a chemical change.

Molecules of gasoline go through a chemical change when they burn in the engine of a car. Coal is changed chemically when it burns, as it gives off light and heat.

It is a chemical change in the molecules of the paraffin that causes a candle to give off light.

AN INVESTIGATION into Making Light

Needed: a candle, a ruler, a pencil, a candle holder, a clock or watch

Mark inches and half-inches on the candle with the pencil and ruler.■

Put the candle in the holder. Light the candle and write down the time.

Let the candle burn in a place where there are no drafts, so that the flame burns steadily. Be sure that it is a safe place.

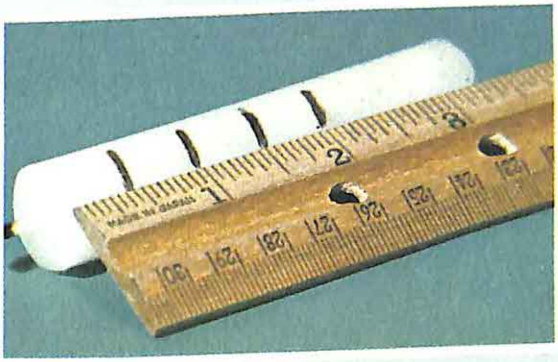
The substance of the candle is called paraffin. How long does it take for half an inch of the paraffin to disappear?

How long does the next half-inch take to disappear?

What appears as the paraffin disappears?

What do you think happens to the paraffin?

Here is what happened in one investigation.● ▲ ◆ How can you explain the change that takes place?



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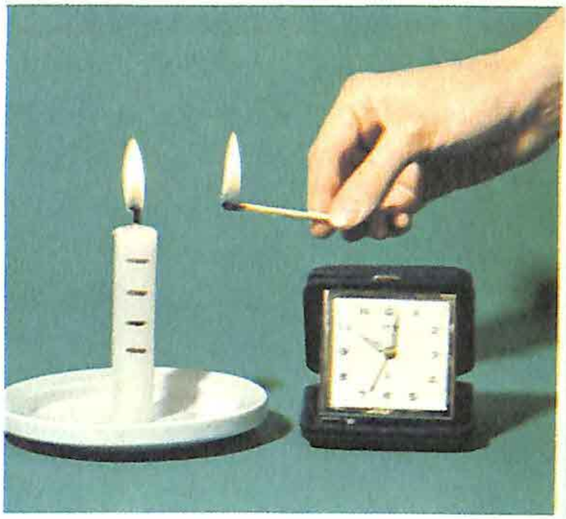

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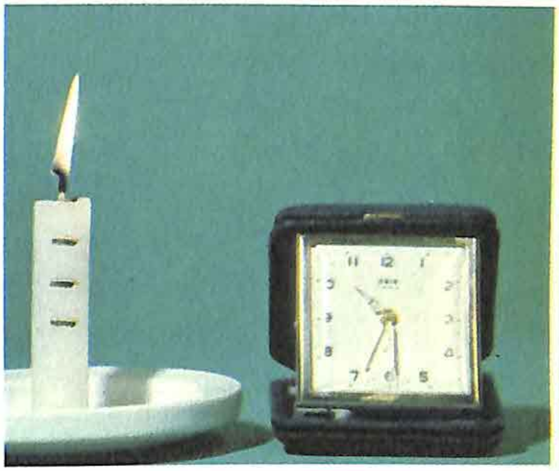

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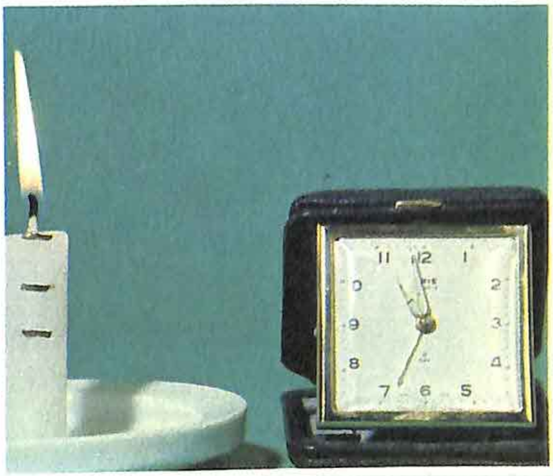

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What the Changing Molecules Do

As a candle burns, a chemical change is taking place. The molecules in the paraffin are changing into other molecules. As they change, they make a flame that gives off light and heat. In other words, as the molecules change, they give off energy.

You eat food so that you will have energy and be able to do the things you want to do. When you wind up a clock, you are giving the clock energy so that it will go. Gasoline is useful because it has energy in it that will make an engine go. Energy, scientists say, is the ability to do **work,** to make matter move.

The paraffin of a candle contains energy. It is chemical energy. When the candle burns, its chemical energy is changed into light energy and heat energy. In other words, as the molecules in the paraffin change into other molecules, they give off light energy and heat energy. When we burn coal, or natural gas, or gasoline, the changing molecules give off energy that we can use.

As paraffin burns and gives off energy, its molecules are changed into other molecules. What other molecules does paraffin change to? See for yourself. Try the investigation on the opposite page.

The Chemical Change of a Candle

As the candle inside the jar burns, its molecules change into other molecules. A chemical change takes place.

What collects on the jar above the flame as the candle burns? Little drops gather on the glass. They are drops of water. When paraffin burns, molecules of water are formed.

What happens to the limewater as the candle burns? At the beginning, the limewater is clear. As the candle burns, however, the limewater becomes cloudy and white.

When clear limewater turns a white or milky color, it means just one thing. It means that carbon dioxide molecules have entered the limewater. Limewater turns milky when carbon dioxide is present.

The limewater in the pan turns a milky color as the candle burns, because carbon dioxide forms as a candle burns. Some of the molecules of paraffin are changed to molecules of carbon dioxide.

Thus the paraffin of the burning candle goes through a chemical change. The paraffin changes to water and carbon dioxide. As this chemical change takes place, the chemical energy of the paraffin in the candle changes. It changes into light energy and heat energy.

AN INVESTIGATION into a Chemical Change that Makes Light

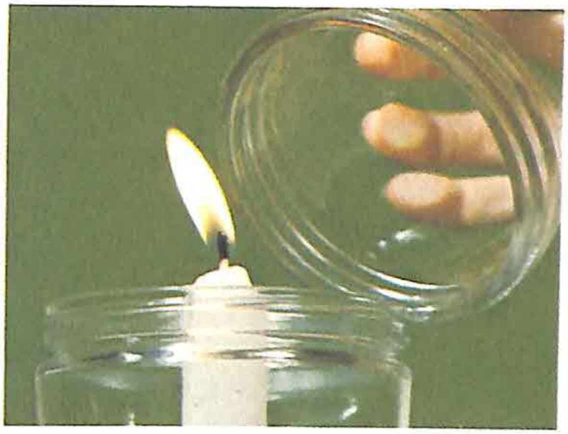
Needed: two jars, a short candle, a piece of tape, limewater

Stick the short candle in one jar with melted wax. Blow out the flame and pour about an inch of clear limewater into the jar.■

Be sure the second jar is dry. Light the candle. Carefully lower the mouth of the second jar on to the mouth of the first jar. Let it rest there.●

The candle will burn for a few moments in the jar. What happens in the jar above the flame?

After the candle has gone out, use the tape to join the jars together without letting air in. Then shake gently so that the limewater and the air in the jars are mixed. What happens to the limewater? Here is what happened in one trial.▲ ◆



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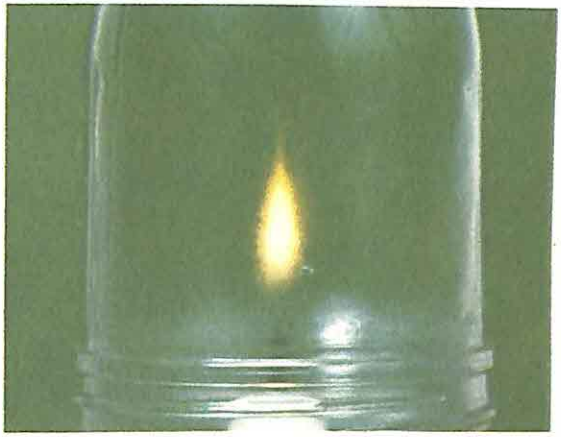

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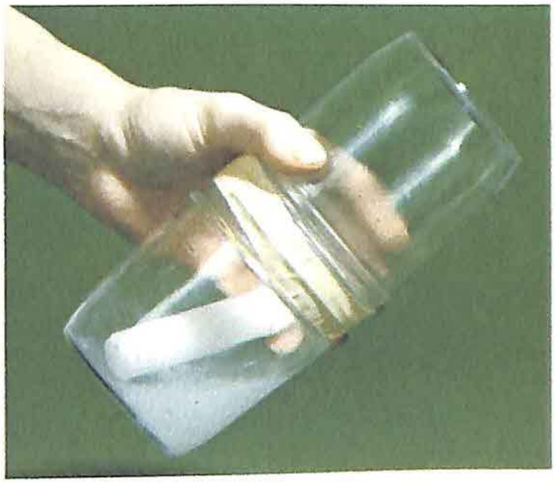

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What makes the light of a candle? The answer is chemical energy. Molecules are rearranged to form other molecules. As this chemical change takes place, energy is given off. That is the story behind the common event we have been investigating, a candle burning.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. The flame of a candle is made by
   a. molecules disappearing into the air
   b. molecules rearranged to form other molecules
2. In a chemical change, molecules
   a. do not change
   b. are rearranged to form other molecules
3. The light and heat of a candle come from
   a. chemical energy b. unchanging molecules
4. A burning candle gives off water and
   a. carbon dioxide b. nitrogen

5. How Light Travels

You flip a light switch. At once light reaches all parts of the room. You push the switch on a powerful flashlight. At once the beam hits the target, no matter how far away it is. Light seems to take no time at all to get somewhere. But light does take time to travel. Light travels so fast, however, that ordinarily we cannot notice the time. Light travels at the speed of *186,000 miles in one second.* Light does not take much time to cross your room, then, when you flip the switch. Just the same, it does take some time.

How does light travel?

The investigation on the opposite page will furnish some evidence to answer this question.

AN INVESTIGATION into How Light Travels

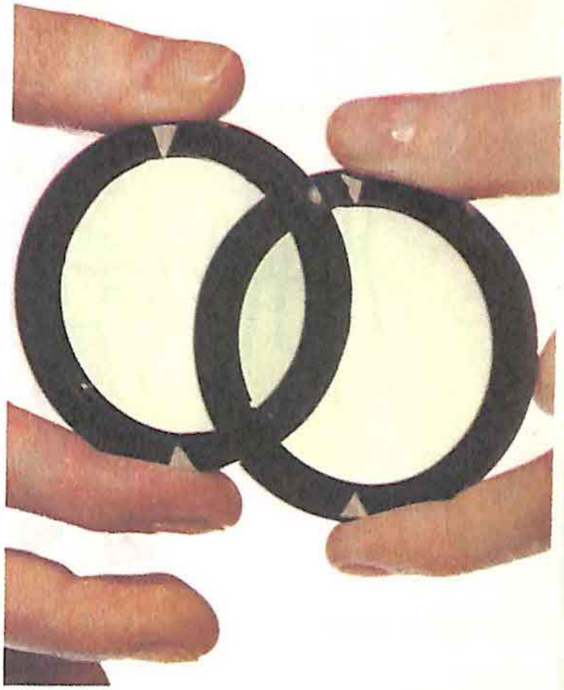
Needed: two pieces of polarized (POH-luh·riz'd) plastic or glass

Look through one piece of polarized plastic. Does light pass through it? Turn the piece, like this. ■ Does light still pass through? No matter how it is turned, light passes through it.

Do the same with the other piece of polarized plastic. The results are the same.

Now place one piece on the other, and look through both. Turn one of the pieces, holding the other piece still. ● What happens as one of the pieces is turned? ▲

How can this behavior of light be explained?



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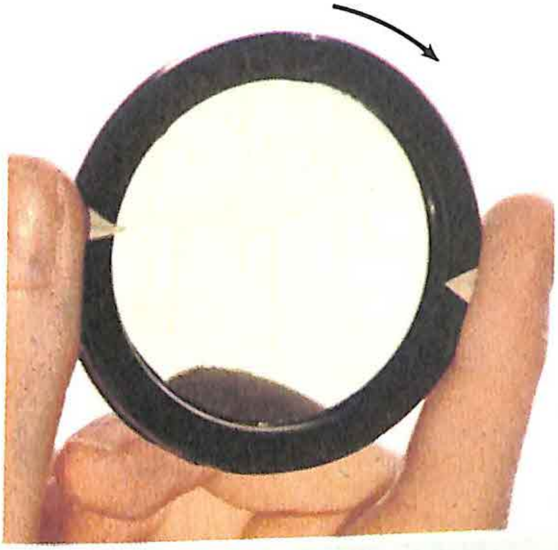

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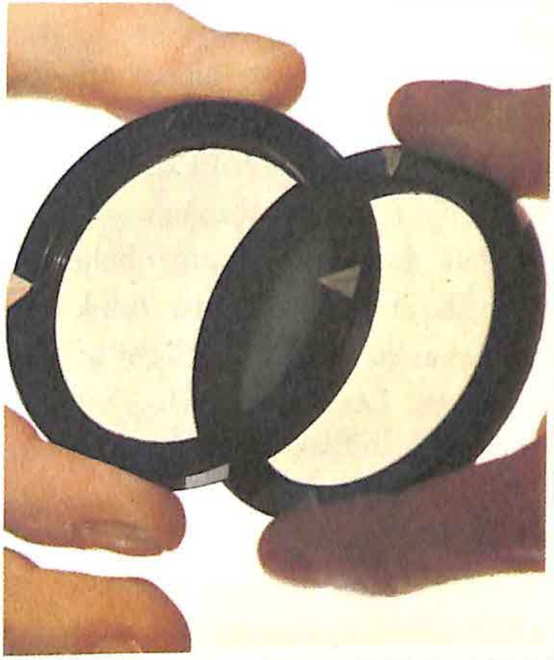

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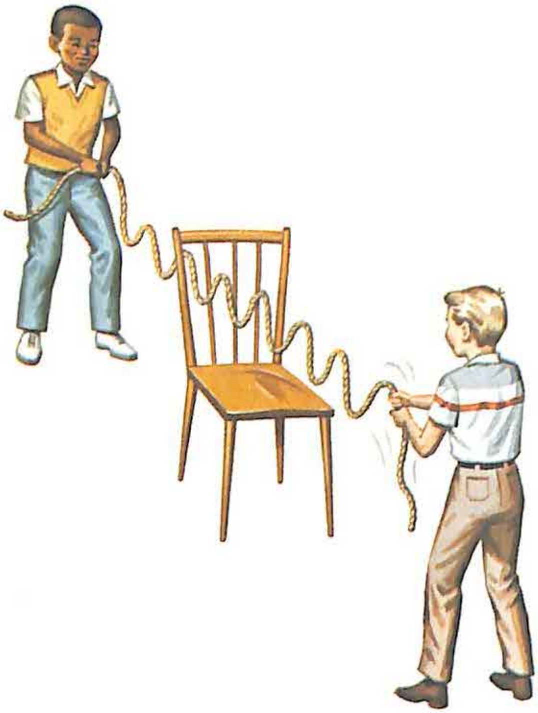


How the Light Is Stopped

Light passes through each piece of **polarized** plastic, no matter how you turn the piece.

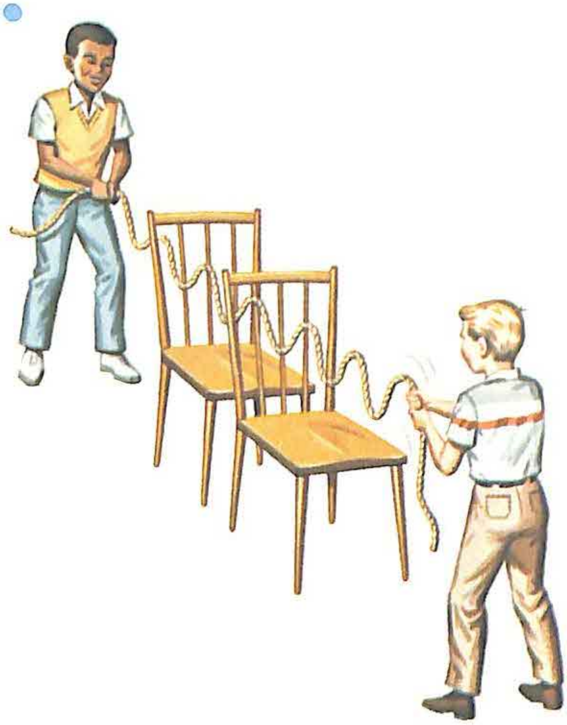
Yet when the two pieces are together in a certain position, light cannot get through them. In another position, light can get through.

What does this strange behavior mean about light? Scientists think that this behavior means that light travels in waves. Let us see why, with a **model.** Scientists make models in order to help themselves to understand things. They make models of airplanes and rockets, models of things you can see. However, scientists also make models of *ideas* they have. For example, scientists make models of atoms. They make models of things they need to explain.

Can we think of a model that behaves like light and polarized plastic?

Here is a chair, a rope passing through the back of the chair, and two boys. One of the boys is sending waves along the rope by flipping the end. The waves pass right through the back of the chair, along the rope to the other boy.

Now another chair is placed beside the first one. Even with two chairs, the waves along the rope pass through.

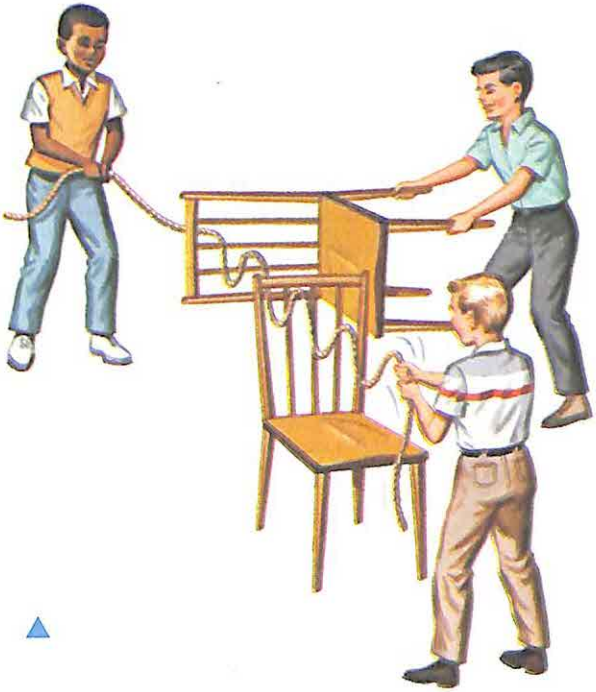


Now, however, one chair is turned this way.▲ Now the chairs block the waves. No waves can pass through the second chair.

By turning the chair around still farther, waves can go through again. They can pass when the two backs are in line.

What does this model show us? It shows that there is a way of stopping *waves*, a way that works like the polarized plastic. It suggests to us that light is made up of waves. The way light behaves as it passes through polarized plastic makes us think that light travels in waves. When you switch on a light, perhaps waves of light rush out from the bulb in all directions.

Scientists have done many, many experiments which show light behaving as if it were made up of waves. But scientists have done other experiments which show light behaving as if it were made up of tiny *particles!*



Is light made up of waves, or of particles, or of both? It is a mystery you will hear more about later. At this moment scientists have two explanations of how light behaves. Sometimes light acts as if it is made up of waves. At other times light acts as if it is made up of particles.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Light travels at the speed of
   a. 186,000 miles per second b. 186,000 miles per hour

2. The way light behaves with polarized plastic makes us think that light may be made up of

a. waves b. particles

3. Sometimes light behaves as if it were made up of

a. particles b. molecules

USING WHAT YOU KNOW

1. Suppose you wanted to shut out light from a room. How could you do it by using polarized plastic?

2. How are sound waves different from light waves?

6. The Main Concept: How Light Behaves

Can you look back and remember what your idea of light was before you began this unit? Surely you have learned some things about light that you did not know before. Surely you have an idea of light that is different from the one you had at first.

You know that light
—travels in straight lines
—can be reflected
—can be absorbed
—can be diffused
—can be bent
—travels in waves sometimes
—travels in particles sometimes.

To make light, we burned a candle. As it burned, the candle went through a chemical change. As it burned, it gave off heat and light. The chemical energy in the paraffin was changed into heat energy and light energy.

Do we have to burn something whenever we make light? No, indeed. For instance, striking two stones together can make a spark of light. The Sun's light is not the result of burning. Nothing is burning in a glowing electric lamp. But whatever the light, it takes energy to make it. Striking stones together takes energy. The Sun is using up energy. An electric lamp uses up energy as it glows.

It seems that to make light, one form of energy is changed to another. This is true whether the light comes from the Sun or whether it comes from striking two rocks together.

Energy can be changed from one form to another.

Fixing the Main Concepts

TESTING YOURSELF Study the statements below and choose the correct responses. Your study will help fix in your mind the main concepts of this section.

1. Light, like sound, can
a. be reflected b. go around corners

2. A black cloth
a. absorbs light b. reflects light

3. A shiny metal
a. absorbs light b. reflects light

4. A lens can
a. absorb light b. bend light

5. The idea that light travels in waves explains what happens when light is stopped by
a. polarized plastic b. ordinary glass

6. When a lens focuses light, the light is being
a. diffused b. bent

7. At the back of your eyes is the
a. retina b. lens

8. Work by scientists shows that light can behave as if it were made of
a. atoms and molecules b. waves and particles

9. An explanation in science
a. is always true b. may change

10. Light is a form of
a. energy b. matter

FOR YOUR READING

1. *Explorations in Science: A Book of Basic Experiments*, by Harry Milgrom, published by E. P. Dutton, New York, 1961. There are many investigations on both light and sound in this book. It will help you go further in exploring light and sound.

2. *The First Book of Photography*, by John Hoke, published by Franklin Watts, New York, 1954. This book offers you a good beginning in the study of photography.

GOING FURTHER

Compare the human eye with a camera. How are they the same? How are they different?

Find out how the eye works, especially how the lens and retina work. What does light do when it hits the retina?

How does the film of a camera capture light? What happens to the film?

A New View of Sound and Light

Your idea of what light and sound are like has changed from what it was. You have a new idea of what light and sound are like—a new **concept** of light and sound. What is a concept? It is something important and useful to you. Let us see why.

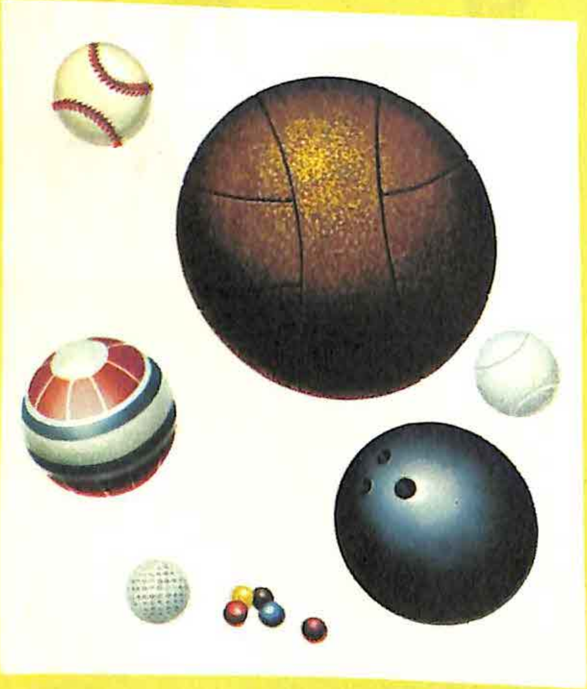
What Is a Concept?

Look at the animals on this page. ■ What sort of animal are they? You have no trouble recognizing them. They are all dogs, of course.

■

Here is something strange, however. Every one of these dogs is different. Perhaps there is a kind of dog here you have never seen before. Even so, you know it is a dog. How can you know what something is that you have never seen before? How do you know that all these different-looking animals are dogs?

You know that all these different animals are dogs because you have in your mind a *general idea* of what a dog looks like. You have put together this general idea of a dog from all the dogs you have seen. This general idea is called a concept. You have a concept of a dog in your mind. Because you have this concept, you can recognize dogs when you see them, even though they are different. Because you have a concept of a dog, you can recognize a dog even though you may never have seen that kind of dog before.



Here is another example of a concept. Use your imagination for a moment. How many different kinds of balls are used in games? ■ Big ones. Small ones. Different colors. Different materials. Baseballs, golf balls, rubber balls, basketballs. tennis balls, marbles, ball bearings, wooden balls, bowling balls. All different, yet you have a general idea of the way in which all these different balls are alike. You have a concept which helps you to recognize an object as a ball. It is built up from many observations.

Think for a moment and you will find that you have many different concepts in mind. Why? Because concepts are very useful things.

What Use Has a Concept?

It is hard to imagine such a thing, but suppose that you did not have a concept of what a ball is like. Every time you saw a kind of ball that you had not seen before, it would be something new.

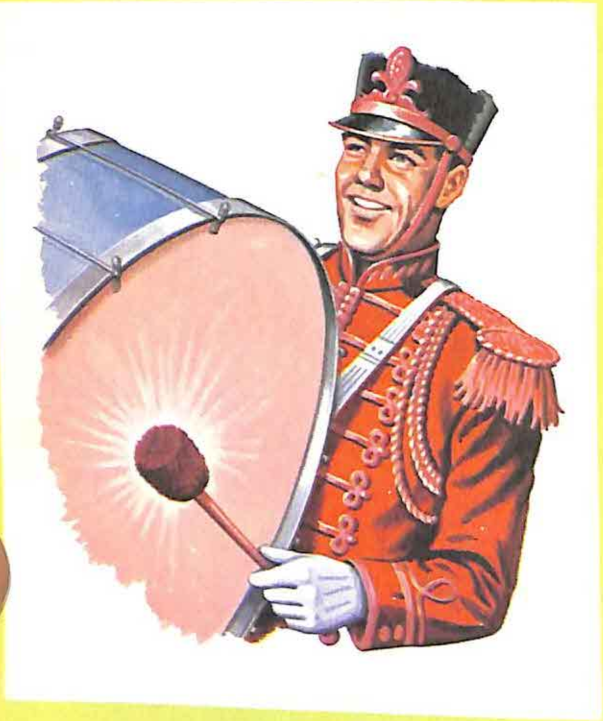
A concept brings together, or relates, a lot of different things that are somehow alike. Here is a basket of balls. ● In what ways are they different? In what ways are they alike? A concept is like a basket in which you put certain things that are alike in some ways. Like a basket, a concept can collect together in one place many different things that are somehow related. Like a basket, a concept makes things easier to carry in your mind.

Here is another way in which a concept is useful. Imagine that you meet someone who has on a leash an animal you have never seen before. "What is it?" you say. "It's a kind of dog," the owner replies. "Oh," you say, "a dog!" Now, all at once you know a good deal about this strange animal. What you know about dogs in general holds good for this new one. Your concept of a dog has come to help you.

Concepts are useful because they bring together, or *relate*, things that would be scattered about in your mind. Concepts are useful because they help you to understand new, strange things. Concepts help make order out of disorder and help you to understand the world you live in. So concepts are especially important to

●

scientists, who try for order and understanding of how the world works.



■

Light and Sound

You have a new concept now of light and of sound. These new concepts help you to understand light and sound. When you hear a sound, no matter what it is, you know that energy is being used to make something vibrate to and fro. The sound waves travel through the air to your ears. When you see a light, you know that energy is being used to make light waves that reach your eyes. When you see sunlight, you know that the light waves are traveling through space.

You know that sound and light both use energy. The sound of the starter's pistol at a race is heard because the chemical energy in the gunpowder is turned into sound energy. The light of a candle is seen because the chemical energy in the paraffin is changed into light energy.

When you hear the sound of a bass drum, you know that the energy of the moving drumstick is being changed into the energy of the moving drum. ■

When you turn on an electric light, you start the energy of electricity turning into the light energy. ●

Here, then, is another concept, one

that connects the concepts of light and sound. It is that energy can be changed from one form into another. Chemical energy can be changed into sound energy. Chemical energy can be changed into light energy and heat energy. The energy of movement can be changed into sound energy. The energy of electricity can be changed into light energy. Rub your hands together, hard. What is the energy of movement of your hands changed to? Heat energy, as you can feel. Clap your hands together. What is the energy of movement of your hands changed to now? To sound energy.

Energy can be changed from one form to another. Here is a concept that must connect many different things, for we live in a world of energy. You will hear more of it.

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

(Text pages 60–97)

Unit Three

THE TRAVELS OF A DROP OF WATER

UNIT CONCEPT
A loss or gain in energy affects molecular motion.

Children observe and develop an understanding of the behavior of water in different forms, the importance of water to life, and the energy changes involved by means of concepts such as the molecular theory and energy transformation. As they do so, children obtain a better understanding of how scientists think and work.

A VIEW OF THE UNIT

A Preview of the Concepts

Everyone has observed that water can disappear. Puddles made by rain vanish when the Sun comes out. Wet clothes dry on the clothesline. Wet raincoats dry out. Everyone has observed that water disappears. But scientists ask: Why? How does water disappear? What does it mean? And young children also ask these questions, fortunately.

Evaporation and Condensation

A good place to begin is by watching a drop of water disappear, but under special circumstances. For this investigation, the water is made to disappear inside a glass chamber made from two jars; and the disappeared water is made to appear again. Warming the water makes it vanish, cooling makes it appear again; a pattern begins to be seen. By thinking of the water as molecules—by using the molecular theory—what happens when water evaporates is explained: visible liquid becomes invisible gas, but the water molecules are there just the same.

There are water molecules in the air around us. An investigation with a shiny tin can and ice water shows how some of the water vapor in the air can be made to condense by cooling, and to become liquid water on the side of the cold can. This happens because cold air cannot hold as many water molecules as warm air. The all-important concept of how energy is involved in these changes from gas to liquid and from liquid to gas is introduced. Heat energy is taken in when water evaporates. Heat energy is given off when water vapor condenses.

Expansion and Contraction

As another investigation shows, warmed air expands and cooled air contracts; molecules move farther apart or closer together when heat energy is supplied or taken away. Adding this concept to the concepts already developed, how a cloud forms can be accounted for, and what a cloud is can be understood.

One more investigation with the sealed glass chamber of jars taped mouth-to-mouth allows children to discover one way that the tiny water droplets the cloud is made of can become raindrops. The growth of droplets into drops, by collisions, can be seen on the sides of the chamber. How rain is made is not yet fully understood by scientists, however; it is a subject for more research.

Currents

Warm and cold water behave like warm and cold air. Warm water rises in cold water, cold water sinks in warm water, as an investigation illustrates. The wind can push water along. These things help to explain the presence of "rivers" in the oceans, currents like the Gulf Stream and the Japan Current. Another one of the travels of a drop of water is discovered.

Everyone drinks water, of course, but it may come as a surprise to the children to find how important eating water is. Much of the water we need we obtain in the food we eat. An investigation makes way for the discovery of what part of an apple is water, and the question of how the water gets into the apple is followed up. The travels of a drop of water are extended again.

Everyone drinks water, but few stop to think of what must be done to provide a glass of drinking water. An investigation allows the filtering of water through sand to be observed, as one water purification process. The importance of the water table level for one kind of well, and of a water-carrying layer of rock for another kind, is developed.

Water Cycle

Finally the travels of water are summed up with the unifying concept of the water cycle. Children find that molecules of water are not used up and thrown away, so to speak, but used over and over again, around the world. The water cycle must be kept going, however, which takes energy. Where does this energy come from? From the Sun.

SUPPLEMENTARY AIDS

All films and filmstrips below are in color. All have been evaluated and they are considered to be of approximately the right content and level of difficulty for the grade. Names and addresses of distributors and suppliers are on page F-25.

Films

Water and What It Does (11 min.), E.B.F., 1964. Illustrates the basic concepts about the nature and properties of water; the dissolving property of water; the processes of evaporation, condensation, and expansion; the force of expanding water vapor, or steam, and some of its uses.

Water in the Air (12½ min., sound), Cenco, 1963. Explains how the water in the air around us helps determine the kind of weather we have; how water changes into one form from another—liquid, gas, solid; and how the continuous process of evaporation and condensation of water in the atmosphere produces the water cycle.

What Makes Weather (14 min., sound), Cenco, 1963. Explains the basic reason behind weather changes; how variations result from changes in the air—according to its temperature, pressure, motion, and moisture content; what causes lightning and thunder.

Solids, Liquids, and Gases (9 min.), McGraw-Hill. Shows how a substance, water, can be changed from one state to another depending on heat and cold; introduces the three states of matter.

Things Expand When Heated (10 min.), McGraw-Hill. Shows the movement of molecules before and after heat is applied to them; explains expansion and contraction; provides an introduction to the molecular theory.

Rain (10 min.), I.F.B. Explains the water cycle and why it is important to man; also the phenomenon of the rainbow.

A Visit to the Waterworks (11 min.), E.B.F. A trip to a waterworks clearly shows how water is treated before it is safe for use by man—chemically treated, filtered, and tested.

Filmstrips

Story of Rivers (50 frames), E.B.F., 1953. Explains how running water helps form rivers; what is underground water; what determines the water table.

Structure of Plants (44 frames), E.B.F., 1962. Shows how roots and stems grow; how roots absorb water and chemicals from the soil; how leaves need sunlight, air, and water to make food. All living plants need water.

How Heat Causes Expansion (40 frames), Jam Handy, 1959. Explains that all matter is made of molecules; how heat causes them to vibrate faster (expand); how cooling causes them to vibrate more slowly (contract); gives simple investigations with water, showing changes into different forms; water cycle.

Weather (46 frames), McGraw-Hill, 1953. Drawings show that weather changes because of air temperature, air pressure, air movement, and air moisture; shows how clouds are formed; what causes rain, snow, and hail; how man is able to forecast weather; explains water cycle in nature.

Why Does It Rain, Snow, Hail, and Sleet (39 frames), S.V.E., 1960. Animated drawings explain what causes evaporation; what is relative humidity of air; what causes condensation; how clouds are formed; what conditions cause rain, snow, sleet.

Science in the Magic Story of Water (62 frames), L.F.S., 1961. Explains by means of simple investigations what the water cycle is; how man uses and controls water; how water provides a home for some animals; why it is important to conserve water.

Science Reading Table

Starred (*) titles are especially recommended as having suitable and readable sections for enlarging upon the content and concepts of this unit. The full names and addresses of the publishers are on page F-24.

About Our Weather, by Gertrude Hevener Gibson, Melmont, 1960. A teacher and pupils study the weather throughout this conversational story. A few easy investigations are tried and observations of weather phenomena are reported by the pupils. Touches upon wind, clouds, rain, thunder and lightning, and a rainbow.

(Easy)

About the Land, the Rain and Us, by Terry Shannon, Melmont, 1963. Touches upon the importance of soil and water. Shows how soil is the starting point of the food chain. The water cycle and importance of the balance of nature are described. (Easy)

Everyday Weather and How It Works, by Herman Schneider, McGraw-Hill, 1961. Describes how to make a weather-forecasting station. Includes information on weather maps, cloud seeding, and rainmaking. (Average)

°*The Sea,* by Leonard Engel and the editors of *Life,* Time, Inc. From the *Life* Nature Library, Silver Burdett, 1964. A comprehensive story of the sea with the beauty and enticement of the original *Life* publication, but with simplified narrative. Teachers and children will enjoy using this book together. Contains information on the beginnings of the sea, waves and tides, and plant and animal life of the sea. (Advanced, but average readers will enjoy selected passages)

°*The Water Story,* by George Shaftel and Helen Heffernan, L. W. Singer, 1963. Two fictional stories contrast situations of too much water and too little water. The major portion of the book then deals with our need for water, flood control, dams and waterways, and the pollution problem. Excellent material for both acquisition of facts and development of attitudes and understandings. (Average, but less capable readers will enjoy selected sections)

°*The Way of the Weather,* by Jerome Spar, Creative Educational Society, 1962; in cooperation with the American Museum of Natural History, New York. Explains in nontechnical language what the atmosphere is made of, the kinds of weather and climate found at different seasons and in different parts of the world, how weather observations are made and reported. Gives instructions on how to make simple weather observations. Photographs and diagrams supplement each page of text. (Advanced, but average readers will find it useful reference on selected topics)

What Is Water, by Adaline P. Hagman, Benefic Press, 1960. A survey of the principal characteristics of water. The physical and chemical forms are described briefly. The action of water is described in relation to land and weather. Many illustrations increase the usefulness of the book for young pupils. (Average)

°*What Is Weather,* by John B. Syrocki, Benefic Press, 1960. Contains information on moisture in the air, the causes of temperature, air movements, weather instruments, storms; also weather prediction. Many illustrations and diagrams relate the information to facts children already know about the weather. (Average)

▶ INTRODUCING THE UNIT

Equipment and Materials

. . . a glass

. . . water

As the class watches, pour some water into a glass from a pitcher or tap. Set the glass where all the children can see it. After they have looked at it for a few moments and are beginning to wonder what it is there for, ask "What do you see?"

The answer will be water, of course. If you say "Is that all?" the glass will be identified, probably with some satisfaction. Now if you repeat "Is that all?" there may be some surprise. But someone may recover and say, "I see the stuff we drink. . . ." You are launched on the game of identifying all the uses and features of water that the children can think of, which can be kept going as long as you see fit by repeating "Is that all?"—or by allowing each child who answers the question to ask it of a classmate. Needless to say, the group will supply more interesting answers than an individual member can think of. When this has gone on long enough, turn to the unit opening on pages 60 and 61.

(*Text pages 62–65*)

SUBCONCEPT
Water evaporates to become a gas, water vapor.

Processes emphasized

Observation
Analysis of observations
Investigation (with design of an experiment)
Hypothesizing
Theorizing
Prediction

Section 1: THE DISAPPEARING DROP OF WATER

Children begin to examine the familiar behavior of water in the ways of the scientist, and so to increase their understanding of science.

Introducing the Concept

You may want to propose the final sentence of the unit opening as a question: How can a drop of water be put back up in the sky? Some knowledgeable youngster may reply at once that you put some water in a dish and let it evaporate. Such a statement provides the opportunity for further questions, of course.

What does "evaporate" mean? What happens to the water so that it actually disappears?

And, anticipating the investigation, can anyone think of a way in which the same water can be made to appear again after it has disappeared? As answers are offered you may want to bring forth the materials for the investigation one at a time, setting them where they can be seen. Then read as far as **How Water Behaves,** text page 62, and do the investigation.

Water becomes an invisible gas and returns to a liquid.

Developing the Concept

The investigation. Use a very small drop of water in the glass, and use large glasses (or jars), so that evaporation will not be too limited. Be sure that the glasses are dry to begin with. If it is a humid day, so that the air is already well loaded with water vapor, warming the glasses a little will help dry the air in them.

Equipment and Materials

See text page 63; also the Teacher's Manual for *Classroom Laboratory 4.*

As the photographs show, the drop of water in the glass chamber can be made to disappear by heating the air in the chamber a little. Water can be made to reappear by cooling the air in the chamber. It is necessary to dry the outside of the chamber (after it has been standing in ice water) so that the water on the inside walls may be seen. Supplying heat energy to the water in the chamber makes it disappear—or evaporate, as the text following the investigation points out. Taking away heat energy from the air in the chamber makes the water reappear. (The term *condensation* is introduced in the next section.)

How water behaves. Water can disappear and appear again. How can this be explained? We turn to the molecular theory and see that if we suppose water to be made up of molecules, the appearance and disappearance can be explained. Here is another example, then, of the usefulness of the concept that matter is made up of molecules; in Unit One the molecular theory helped explain how sound waves traveled.

Evaporation is explained by the molecular theory.

A single molecule is much too small to be seen; but a gathering of molecules may be visible. Imagine that you are in an airplane flying over a football stadium. You are so high that you cannot see the individual players on the field; but you can see where many people are gathered together, in the stadium. The game ends. You can see the mass of people streaming from the stadium. Why can you not see them as they scatter to go home?

Extending the Concept

Equipment and Materials
. . . ice cube
. . . dish

You may want to develop the football stadium idea a little more. Show the children an ice cube on a dish. The ice is a solid, of course. Are the water molecules in the solid ice cube like the crowd in the stadium, the crowd leaving the stadium, or the individuals on their way home? What about the liquid water, as the cube melts? And what of the water vapor evaporating from the water? (The liquid is like the spectators streaming from the stadium and still visible from the airplane. The water vapor, invisible, is like the individuals who have scattered as they go home.)

Speeding up evaporation. Put on the chalkboard two circles of water of about the same size and wetness. How long do they take to evaporate? How can the evaporation of one spot be speeded up? Someone may suggest fanning one spot. What do you predict will happen if one spot is fanned and the other is not? How can you explain what happens? (The molecules of water vapor over the fanned spot are being removed by the moving air and making way for more water molecules to escape.)

What if? What would happen if, one day, water evaporated and never came back? Make up an imaginative story—with pictures—about what it would be like.

Reviewing the Concept

(*Text page 65*)

Before You Go On. 1. b 2. a 3. b

Using What You Know. 1. The molecules of water in an open glass become molecules of water vapor as they evaporate. They enter the atmosphere and circulate with the air. 2. As perfume evaporates, molecules of perfume escape into the air and are distributed in the room by air currents. Your sense of smell detects these traveling perfume molecules.

(Text pages 66–70)

SUBCONCEPT

To condense water vapor, heat energy must be taken away.

Section 2: WATER FROM THE AIR

Children find that invisible water vapor in the air can be changed to water by cooling.

Processes emphasized

- Observation
- Measurement
- Analysis of data (and observations)
- Investigation (with design of an experiment)
- Hypothesizing
- Theorizing
- Prediction
- Library research

Introducing the Concept

Color a very small amount of water with a drop or two of ink, and pour it into a saucer or other wide, shallow pan. Ask for predictions of what will happen if the colored water is exposed to air and heat. Will the colored water be able to evaporate? What will happen? Why? Predictions and explanations should be noted, but not evaluated at this point. Put the liquid in sunlight or on a warm radiator to evaporate—or, for quicker results, heat on a hot plate. The water evaporates and leaves behind the coloring matter of the ink. Why is this coloring matter left? It is a solid and does not evaporate.

What has become of the water molecules?

They are in the air of the room in the form of invisible water vapor. But we can make some of this water vapor in the room return to the form of water. Read as far as **Water in the Air,** and do the investigation.

Developing the Concept

Water vapor in the air can be changed to water.

The investigation. As the water in the can is cooled, a film of water will form on the outside of the can. The film will dull the shiny surface of the can as it forms, so it is important that the can be shiny. If the film is examined with a hand lens or magnifying glass as it forms, it will be seen to be made up of tiny water droplets. The droplets get larger as more molecules of water vapor come out of the air next to the cold can and settle on the metal surface. If the room air is dry, the can must be well cooled before the film of water will form. Passing a finger through the film will collect some water. If the water in the can is allowed to get warmer, the film will disappear as evaporation takes place. How can you show the water did not come from inside the can? (Cover the can.)

Equipment and Materials

See text page 67; also the Teacher's Manual for *Classroom Laboratory 4.*

Water in the air. Cold air cannot hold as much water, in the form of invisible water vapor, as warm air. If air that contains water vapor is cooled enough, some of the water vapor will be forced out of the air and become liquid water. Children who wear glasses may have had them "fog up" on entering a warm room from the cold outdoors. Why? The warm air in the room contains plenty of water vapor. Cooled by the cold glass, some water vapor condenses as a thin film of water.

Water vapor condenses when cooled.

What about the dew we sometimes find on the grass early in the morning? It is water that has formed by condensation of the warm air on the cool blades of grass and leaves. In fact, the temperature at which the water vapor in the air condenses and forms water is called the "dew point."

Cool air cannot hold as much water vapor as warm air. For instance, the air in an average-size classroom can hold about 1 pound of water when the air temperature is about 70° F. At 50° F. it can hold about $\frac{1}{2}$ pound; at 90° F., about $1\frac{3}{4}$ pounds of water is water vapor.

Evaporation takes heat energy, condensation gives up heat energy.

It takes energy. Molecules are always moving; we cannot see them in motion, but we can see the result of molecular motion. Dip just the tip of a pen into India ink or carbon ink (available from art supply stores). Lightly touch the tip of the pen to a drop of water on a glass slide: the less ink in the water, the better. Observe the drop through a microscope, and you may see tiny black particles of ink jiggling about, constantly on the move. What causes this motion? The particles of ink are being bumped by moving water molecules, on all sides but unevenly.

Equipment and Materials

. . . microscope
. . . India ink
. . . glass slide

If the drop of water is warmed, will the jiggling speed up or slow down? Light energy reflected by the microscope mirror will turn to heat energy in the drop and warm it, and the motion will speed up. The more heat energy the water has, the faster the molecules of water move. The faster they move, the more easily they can escape into the air—that is, evaporate and become water vapor. The process can go the other way, too. If heat energy is taken from water molecules moving about rapidly in the air as water vapor, they will slow down. If enough heat energy is taken from the vapor molecules, they will become liquid water.

Extending the Concept

Equipment and Materials

. . . small piece of cloth
. . . thermometer

How can you show that evaporation of water takes heat energy? Some of your children may enjoy this problem. One way is to tie a small piece of cloth around the bulb of a thermometer. Then, when the temperature reading has steadied, dampen the cloth around the bulb with water. What happens to the temperature of the cloth? Why? The temperature goes down because water is evaporating from the cloth around the bulb. Evaporation requires heat energy, however, and the evaporating water is taking heat from the cloth and the thermometer. So the temperature of the cloth and the thermometer goes down. What will happen to the temperature reading when all the water has evaporated from the cloth? It will go back up to room temperature.

"*Paddle to the Sea*:" Where does water go when it leaves your community? Where does water evaporate in your community? Why don't the oceans overflow, since so much water is flowing into them? *Paddle to the Sea* by Holling C. Holling, published by Houghton Mifflin Company, is a charming and beautifully illustrated classic describing the journey of a toy canoe from the Great Lakes to the Gulf and suggesting answers to these questions.

Reviewing the Concept

(*Text pages 69–70*)

Before You Go On. 1. a 2. a 3. b 4. a 5. a

Using What You Know. 1. As the water on our skin evaporates, it takes heat from our skin, and so cools us. 2. As in the investigation with a shiny tin can, the film of water on the outside of a cold glass has condensed from water vapor in the air around the glass.

(*Text pages 76–80*)

SUBCONCEPT

Rain forms as cloud droplets come together into larger drops of water.

Processes emphasized

Observation
Analysis of observations
Hypothesizing
Investigation (with design of an experiment)
Theorizing
Prediction

Section 4: A DROP OF RAIN

Children develop understanding, based on previous concepts, of how a cloud may produce rain and snow.

Introducing the Concept

You may want to suggest to the children that they take a closer look at the subject of rain. For example, how much rain falls in your area during an average rainfall? The local weather bureau office or the local newspaper may be able to tell you the average rainfall during a shower. Multiply the depth of the fall by the area of your community to get an idea of the volume of water that comes down. Rough figures will serve well enough to give an idea of the surprising quantity of water that comes from the sky during a rainfall.

What makes rain happen? How does a cloud make rain?

You may want to take some more or less educated guesses from the class, then read up to **Inside the Glass Chamber** (page 76), and do the investigation.

Children begin to understand how condensation can produce rain.

Equipment and Materials

See text page 77; also the Teacher's Manual for *Classroom Laboratory 4.*

Cloud droplets are formed by the cooling of water vapor.

Developing the Concept

The investigation. Two large wide-mouthed jars can be used, instead of glasses, to make a setup that all can see. If a warm radiator or sunlight is not available, put hot water into the bottom jar. Soon after it is sealed on, the upper jar will become clouded with a thin film of condensed vapor from the water in the lower jar. As this film is watched closely (a magnifying glass may help), it will develop into visible droplets, which will collect into larger drops. They may become large enough to run down the side of the glass or to drop from the top, returning to the water at the bottom. Here we have a water cycle in miniature, then. Water becomes water vapor which becomes water again. The concept of the water cycle is introduced in the last section of the unit (page 93), but you may want to touch on it at this point if you think it desirable.

Inside the glass chamber. Water goes from the bottom to the top of the chamber as vapor, and from the top to bottom as liquid. What makes it go? What do we know it must have, in order to go? (Energy.) What kind of energy is being used? (Heat energy.) Where does this heat energy come from? (From the Sun, or from the warm radiator, or from the hot water put into the jar—depending on which method you are using.)

Some children may enjoy looking a little more closely at this energy situation. Heat energy is being used, but for what? (To make water vapor out of water. The water has to have heat energy to evaporate.) But condensation is happening too; what about energy there? (Condensation releases heat energy, as the molecules slow down.) Why must energy be put into the chamber, then? (The energy released by condensation escapes through the sides of the jar. So this energy is no longer available.)

The same thing is true when a cloud is formed out of water vapor. The heat energy released, as the vapor turns to liquid droplets of water, escapes into the atmosphere. It is no longer available.

Cloud droplets collide to make raindrops.

The droplets grow. There are other ways in which cloud droplets—or in some clouds, ice specks—make raindrops; the collision method is not the only one. Just what happens is very much a subject for research by meteorologists these days, part of the vast "unfinished business" of science.

You may wish to ask, how can the droplets in the glass chamber be made to grow larger still? The answer is, by applying more heat to the water in the bottom—or by taking away more heat from the water vapor in the top! The children may find that overnight the chamber develops some very large hanging drops. How can this be explained? As the room becomes colder at night, the air in the jar becomes colder. More water vapor condenses, and more water forms.

Raindrops, in spite of common belief, do not assume the tear-shaped form often see in cartoons and comic strips. A drop tends to be round, not streamlined, and as it gets larger it may take on a more and more unstable, trembling, pancake shape, until it comes apart as shown (page 78).

Ice specks melt to make raindrops.

Unfinished business. It happens that specks of ice and water vapor cannot live together quietly in a cloud, so to speak. The specks of ice will grow at the expense of the water vapor. So the specks get larger and heavier. In time they may get heavy enough to fall through the rising air that formed the cloud.

Extending the Concept

Rain in a terrarium. A well-planted terrarium is a good means by which to observe evaporation and condensation. Water evaporates from the plants and the soil, as well as from the surface of the miniature pond. The air in the terrarium becomes loaded with water vapor. Then as the room temperature falls during the night, some of the water vapor condenses on the sides and top of the terrarium. In the morning large water drops are found clinging to the terrarium lid, ready to fall like rain. Why is it that every properly planted terrarium, which is kept covered, rarely needs to be watered?

(Text pages 79–80)

Reviewing the Concept

Before You Go On. 1. b 2. b 3. a

(Text pages 80–84)

Section 5: RIVERS IN THE SEA

SUBCONCEPT

Warm water rises because it expands.

Children come to understand why there are warm currents flowing like rivers in the oceans.

Introducing the Concept

Fill a Pyrex glass pot or beaker with cold water. Add some coffee grounds, or sawdust, or blotting paper shredded into very small pieces.

Equipment and Materials

- . . . Pyrex glass pot or beaker
- . . . coffee grounds, sawdust, or blotting paper
- . . . hot plate or burner

Processes emphasized

Observation
Analysis of observations
Hypothesizing
Investigation (with design of models)
Theorizing
Prediction

Stir until the added material becomes soaked and sinks to the bottom. Now it is ready to show to the class.

Set the container over heat, without saying anything. Watch it, and the children will do likewise. In a few moments the material in the water will begin to move and, as the water gets hotter, it will move more rapidly. It will swirl about in a striking way. Now you can answer the question of what the material is, and you can ask:

What does this behavior mean? How do you explain it?

The material moves because currents flow in the water as heat is applied. Why do currents flow? As the water is heated at a certain spot on the bottom of the container, the water expands. When the water expands, it becomes lighter than the cooler water around it. What happens then? The cooler, heavier water forces the warmer, lighter water to rise. Heated water rises, just as heated air rises, because heated water expands, as heated air expands. Because heated water expands, something happens in the oceans. Read the first page of the section, and do the investigation.

Developing the Concept

Warm water rises in cold water; cold water sinks in warm water.

The investigation. The more gently the cold water is introduced into the warm water (and vice versa), the more striking the movement of the current will be. You may want to try it yourself in private, before it is done in class; not that it is at all hard to do, but rehearsals lead to confidence. The cold water will slowly sink in the warm water, the warm water will float in the cold water. Salt water behaves the same way, as the additional investigation will show. What should happen if the waters are made still warmer and colder? Ask for predictions and reasons, and then for evidence by demonstration. The sinking and rising will be speeded up, of course.

Water containing dissolved substances is heavier than pure water.

Equipment and Materials

- . . . small bottle
- . . . large jar
- . . . ink or vegetable coloring
- . . . salt
- . . . water

Sink or float. If you add a teaspoonful of salt to a cup of water and stir, the salt disappears; it is said to have dissolved. Quite a lot of salt can be made to disappear in the water this way, although there is a limit. The weight of the cup of water is increased by the weight of the added salt. The volume of the water does not change, oddly enough (although, again, there is a limit). This is why salt water is heavier than the same volume of unsalted water. Fresh water, being lighter than salt water, tends to float on salt water. Set a small bottle of colored fresh water in a large jar. Gently add salt water at about the same temperature as the fresh water. What will happen to the colored fresh water when the salt water covers the bottle? (It will tend to float on the salt water.)

Extending the Concept

Equipment and Materials

- . . . candle
- . . . slide projector

Currents in air. The currents caused in liquids and gases by unequal heating are called convection currents. You can see the disturbance in the air above a burning candle caused by convection currents. Place the candle a foot or two away from a light-colored wall. Shine the light from a slide projector on the burning candle so that the candle's shadow is sharply outlined on the wall. Above the candle will be seen the shadow of the swirling convection currents made by rising hot air.

Reviewing the Concept

(*Text page 84*)

Before You Go On. 1. a 2. b 3. b 4. a 5. a

Using What You Know. The Kuroshio current probably contains more fresh water from rivers than does the sea around it.

Section 6: THE WATER WE EAT

(*Text pages 85–88*)

SUBCONCEPT
Water is a component of all organisms.

Children find that much of the water they need they get in the foods they eat.

Introducing the Concept

Equipment and Materials
. . . dish
. . . powdered milk

Processes emphasized
Observation and analysis
Investigation (with design of an experiment)
Hypothesizing
Theorizing
Measurement
Consultation

Put a little powdered milk on a dish. Keep the powdered milk box out of sight, and pass the powder around the class or put it where everyone can examine it. Does anyone know what it is? Touching, smelling, tasting may be allowed. What must be added to powdered milk? (Water.) How is this powder obtained? (By taking away the water in milk, by evaporation.) How much water must be added to this powder to make milk again? (See instructions on the box.) Can you make a drawing on the chalkboard to show what part of this milk is water? Milk is largely water, then.

Do you think all foods have water in them?

Developing the Concept

Plants take in water through their roots.

Equipment and Materials
. . . celery stalk
. . . ink or vegetable coloring
. . . water
. . . two potted geraniums
. . . two plastic bags
. . . string
. . . two or three radish or other seedling plants

The water in an apple. To see how water can travel through a living plant, you or some of the children may want to set a fresh, trimmed stalk of celery in strongly colored water. (Ink or vegetable coloring matter will tint the water.) In a few hours you can see where the colored water has moved up in the stalk of the plant, through the cells; later the colored water may be seen in the leaves. Some idea of the water given off by a living plant can be obtained by setting two potted geranium plants in sunlight. Tie a transparent plastic bag over one of the plants, pot and all. Soon moisture will begin to form on the inside of the bag. Where does it come from? The moisture is condensed water vapor given off by the plant. If someone suggests that the moisture may have come from the soil in the pot, rather than from the plant, put a plastic bag around the second plant, tieing it around the stem just above the soil.

In a six-month growing season a single apple tree may pass about 1,800 gallons of water into the air around it, water which it has taken in through its root hairs and which passes out of its leaves as water vapor. How many gallons in a month is this? Apart from the water you eat, you need six to eight glasses of water daily; a grown apple tree needs about 10 gallons of water daily, on the average. About how many root hairs are at work taking water into an apple tree? To get some idea of the enormous number of root hairs on a plant, make a rough count of the root hairs on two or three radish or other small seedling plants, and average them.

To find out how much water there is in one kind of food, do the investigation on text page 87.

Equipment and Materials
See text page 87; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. You may want to lay another piece of paper towel over the pieces of apple as they dry. Of course the drying process can be speeded up by putting the tray in an oven but lacking that, you can use the scale readings shown in the photographs—while your apple slices are drying out! The photographs present the children with the problem of making the pointer readings on the scale, just as in doing the investigation. You may want to balance any attempts to read the position of the pointer with hairline precision by pointing out that such scales do not work to hairline accuracy. The width of the scale markings gives some indication of this. And has all the water left the apple? Probably not. The youngster who points out that the weight of the plastic bag hasn't been taken into account can be commended; it should be noted, even though the weight is of no account in this case.

Extending the Concept

Water for pets. Do pets need as much water as you do? In one week a chicken will drink almost $\frac{1}{2}$ gallon of water. A good-sized dog needs four bowls of water a day. A cow can drink a bathtubful of water. Some of that water goes into the milk the cow gives. A cat gets water from the milk it drinks. A local veterinarian or pet store manager may be able to tell where to find information about the water requirements of different animals. Using pictures of animals and cutouts, an interesting report or bulletin-board story may be made.

(*Text pages 86 and 88*)

Reviewing the Concept

Before You Go On. 1. a 2. a 3. a

(*Text pages 88–93*)

SUBCONCEPT
The water supply is the result of the cycle of evaporation and condensation.

Section 7: THE WATER WE DRINK

Children gain some understanding of what a good water supply may involve.

Introducing the Concept

Fill a glass with water, from a faucet if one is at hand, and set it where everyone can see it. What is it? How would you describe this water? (Clear, cool, pure, etc.) How did this water get here? (Through pipes in the building, attached to pipes under the streets.)

Where does drinking water come from? Why is it clean and pure?

When the extent of the children's information and ignorance has been sufficiently established, turn to text page 88 and read as far as **Making Water Clean and Pure;** then do the investigation.

Processes emphasized

Observation
Analysis of observations
Investigation (with design of models)

Developing the Concept

Sand can be used to filter some materials out of water.

Equipment and Materials

See text page 89; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. Filtering water through sand can remove very small particles of material indeed from the water; but bacteria, which are smaller still, can pass through a sand filter. Why is cotton placed in the funnel first? Not just to prevent dry sand from sliding out of the funnel. As you may see, filtering water through sand is not a fast process. The greater the area of sand, the more water can be filtered. The cotton in the funnel makes a kind of platform under the sand that increases its useful filtering area at the bottom; this area would otherwise be limited by the diameter of the tube at the bottom of the funnel.

Different processes are used to purify water.

Equipment and Materials

. . . quart jar
. . . soil
. . . water

Making water clean. Settling is easily shown by putting an inch or two of soil in a quart jar, filling the jar with water, and stirring up the mixture so that the soil is distributed in the water. What particles settle to the bottom first? Do all the particles settle?

How does sand filter water? Although the sand particles are tightly packed, they don't fit together very well, so to speak. Their rough and irregular shapes make for very tiny openings between particles. (Filling a pot with potatoes leaves openings between the potatoes.) Only material that is too small for us to see can get through the openings between sand particles. But, strangely enough, this is not the whole story. Sand does succeed in filtering out some material that is smaller than the openings —some microorganisms, for example. This happens because a film forms on the sand grains, and some materials are caught in the film. However, bacteria can get by these obstacles and pass through the filter.

Some swimming pools filter their water by forcing it through diatomaceous earth, a very fine powder made up of diatoms. A swimming pool supply house can provide a sample of the powder and information.

The water table marks the water level in soil.

On the farm or ranch. The water that is poured into sand in an aquarium, as described in the text, does not distribute itself evenly throughout the sand. On the contrary, it collects in the bottom layers. If you dig down, you will find the top layers of sand fairly dry; then you will encounter moisture and find the sand saturated with water. This level, below which the soil is saturated, is the water table. By adding more water you can raise the water table, or lower it by taking water away. If the open bottom of the tin can in the sand is below the water table, water will appear in the can. Water behaves the same way in the soil. A well must reach below the water table to produce water; if the water table drops, the well will run dry.

The water in a layer of water-carrying rock may be under pressure, caused by the weight of water in the layer. So water may gush forth from a well that reaches into such a layer, making an artesian well.

Equipment and Materials
. . . sheet of aluminum foil
. . . sprinkling can

Extending the Concept

A model watershed. A watershed collects and directs raindrops in somewhat the same way as a roof directs the flow of rain, with its gutters and downspouts. Some children might enjoy making a model watershed from kitchen foil, and showing it to the class. Lay a sheet of foil flat on a table. Push the foil from opposite ends so that the sheet crinkles and wrinkles to form a ridge down the middle—a miniature mountain range, in effect. Crease the edge of the foil on either side of the ridge to collect the runoff water. Sprinkle the model with "rain" from above (colored water may help), and watch the paths the water takes on its downhill run. Miniature catch basins may be hollowed out on a slope to act as reservoirs. Notice especially that the runoff is divided into two parts and sent in different directions by the mountain range, making two watershed areas.

Equipment and Materials
. . . two glass jars
. . . soil
. . . alum

Another water treatment. Shake up two similar jars of muddy water. Place one where it can rest undisturbed, and observe how the settling process clears the water of some material as it sinks or settles to the bottom. Settling goes on in reservoirs, for example. Add to the other jar of muddy water a small amount of alum. It will cause a jelly-like mass to form that entraps dirt particles and carries them down to the bottom. This process, called coagulation, is used to help purify water.

(*Text pages 92–93*)

Reviewing the Concept

Before You Go On. 1. b 2. b 3. a

Using What You Know. 1. Watersheds must be kept clean and safe to keep the water that flows from them as clean and safe as possible. 2. In a dry region there is no water table; the well must reach a layer of water-carrying rock, if there is one; hence, a deep well (or an artesian well) must be dug.

(*Text pages 93–97*)

CONCEPTUAL SCHEME
When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT
A loss or gain of energy affects molecular motion.

Why doesn't the Earth run out of water?

Section 8: THE MAIN CONCEPT: AROUND AND AROUND

Children come to understand that the travels of a drop of water are endless; that evaporation and condensation are repeated over and over again in the water cycle.

CONCEPT SUMMARY

The glass chamber constructed with two wide-mouthed jars for the investigation in Section 4 (text page 77) displays the water cycle in a small space. You may want to set it up again. What is going on inside the chamber? Liquid water in the bottom jar becomes water vapor, an invisible gas. And water vapor in the chamber condenses to liquid water, in the top jar. This the children saw before; now the point is that both these things, evaporation and condensation, are going on at the same time, and so no water is used up. The water molecules go up as vapor and down as liquid and up as vapor again, around and around. Now you may want to see whether any of the children have seen some connection between this small chamber and what is happening to water and water vapor in the world around them. Are evaporation and condensation going on at the same time on this globe? What happens to water that evaporates? What happens to water vapor that condenses?

What is the water cycle?

Some child may object that our globe is not closed in, like the glass chamber. Can't water vapor escape into space? The answer is no, for the same reason that our atmosphere does not go off into space: it cannot escape the Earth's gravitation. In effect, our globe *is* closed in like the little glass chamber, so far as water is concerned. When this idea is making some headway, you may want to turn to **The Main Concept: Around and Around,** text page 93, to affirm it and to introduce the proper name for this behavior: water cycle. Then the **Adventures of a Molecule of Water** might present an attractive opportunity to some children to portray them in words, pictures, songs, dances, or whatever.

What keeps the water cycle going?

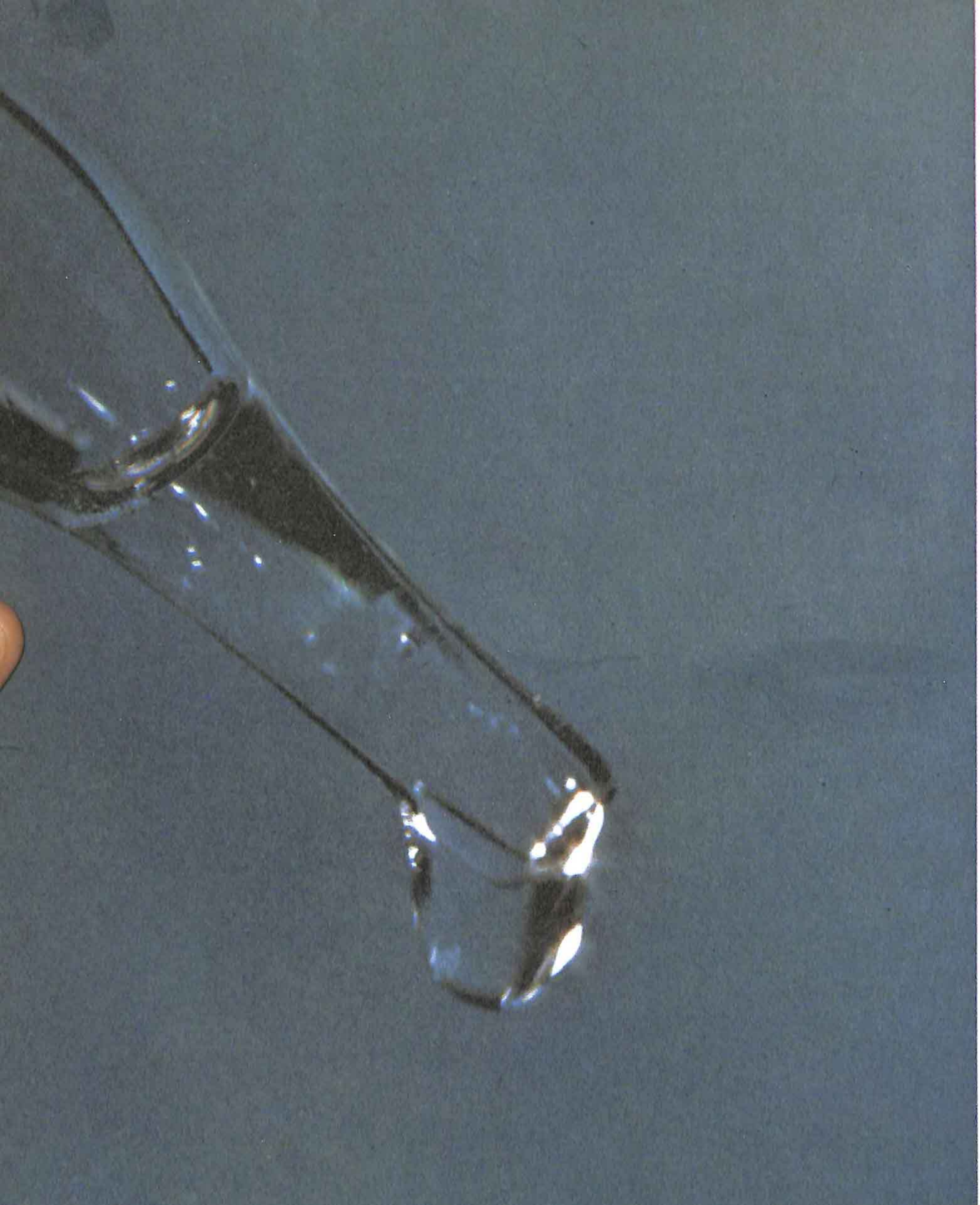
No water has to be put into the glass chamber. The same water molecules are used over and over. One thing does have to be put in, however: energy. Without heat energy the water cycle inside the glass chamber will come to a stop. Without heat energy the water cycle on this globe, Earth, would come to a stop too.

Energy has to keep coming into the glass chamber to keep the water cycle going. Energy has to keep coming into the Earth, too, to keep the water cycle going. For neither the glass chamber nor the Earth is closed in where energy is concerned. The energy that the glass chamber receives passes out of it as it makes the cycle go. Energy that the Earth receives through space from the Sun eventually passes out into space again from the Earth, having done work.

FIXING THE MAIN CONCEPTS

(*Text pages 95–97*)

Testing Yourself. **1.** a **2.** a **3.** b **4.** b **5.** a **6.** b **7.** a **8.** b **9.** a **10.** a



UNIT THREE

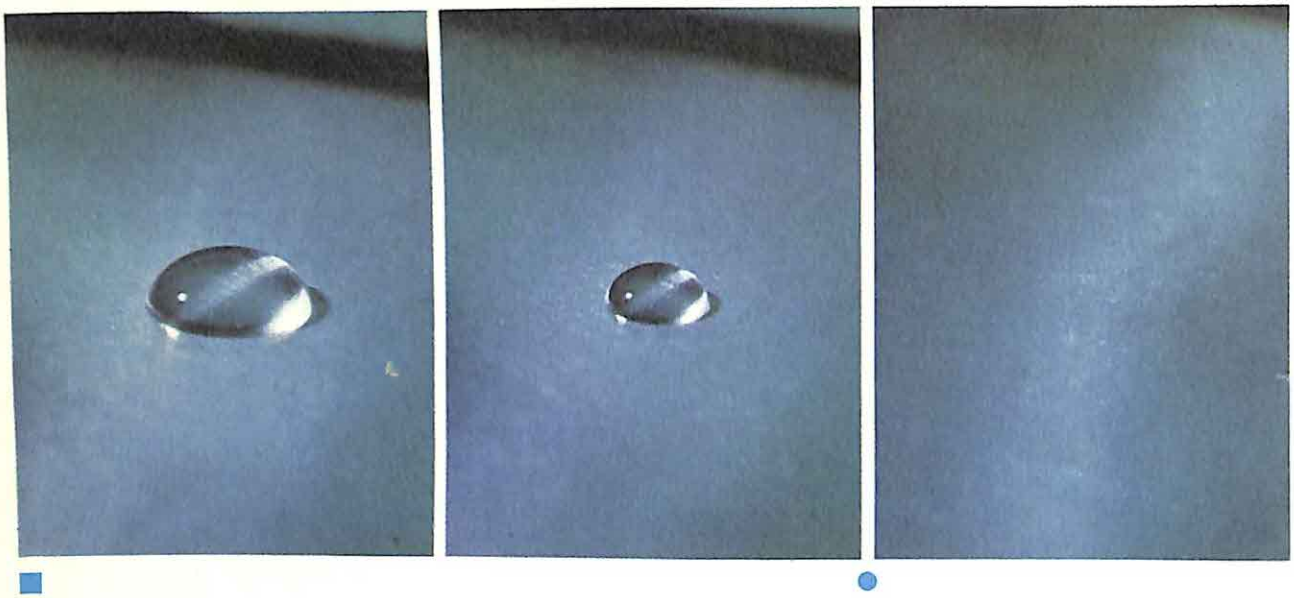
THE TRAVELS OF A DROP OF WATER

There are some things you must have, to stay alive. This medicine dropper holds a drop of one of these precious things. It is water.

You cannot live without water. Plants cannot live without water. Animals cannot live without water.

This drop of water you see fell from the sky. How did it get up in the sky? What made it fall? What happened to it after it fell?

We can begin the travels of a drop of water by putting a drop of water back up in the sky.



1. The Disappearing Drop of Water

Take a dry glass and put one drop of water in it. Put the glass in a warm place—in the sunlight or near a radiator. See the picture marked with a square. ■ Leave the drop of water there. In a while it disappears. ●

Isn't this disappearance rather strange? Water is a substance. You drink it, swim in it, float boats on it. Substances do not just disappear, usually. Yet water does.

Where does that disappearing drop go? You can answer this question by making another drop disappear and then appear again. See for yourself by doing the investigation on the opposite page.

How Water Behaves

Water can disappear and appear again. Let us see how.

Water is a substance. This means that water is made of those tiny bits of matter called molecules. You remember that there are molecules in the air and that they move back and forth when an object vibrates. A solid, too, is made of molecules that are packed tightly together. Sunlight also makes molecules move back and forth, and objects become hot. Any substance—solid, liquid, or gas—is made of molecules. Water, a liquid, is made of molecules, and they can be made to move.

Of course one molecule of water is very tiny. It cannot be seen. However, if a crowd of water molecules

AN INVESTIGATION into a Disappearing Drop of Water

Needed: two glasses, sticky tape, a medicine dropper, ice, water

Take up a little water in the medicine dropper. Put one drop of water in the bottom of one glass. ●

Now tape the two glasses together like this. ■ The tape closes the opening so that nothing can enter or leave the glasses. You have a closed glass chamber with a drop of water in it. What will happen to the drop of water?

Let your glass chamber stand in a warm place, in sunlight or near a warm radiator. What happens to the drop of water in a few hours? Here is what happened in one trial. ▲

The drop of water cannot be seen. It has disappeared. Yet it must be inside. It cannot pass through the glass side. It cannot pass through the glass or the tape around the glass.

Now to bring the water back. Stand the glass chamber in about an inch of ice water, in a bowl. In about 15 minutes, lift out the glass chamber and dry the outside. What has appeared on the inside of the glass? Here is what happened in one trial. ◆

Where did the water go when it disappeared?

What made the water disappear? What made it return?

■

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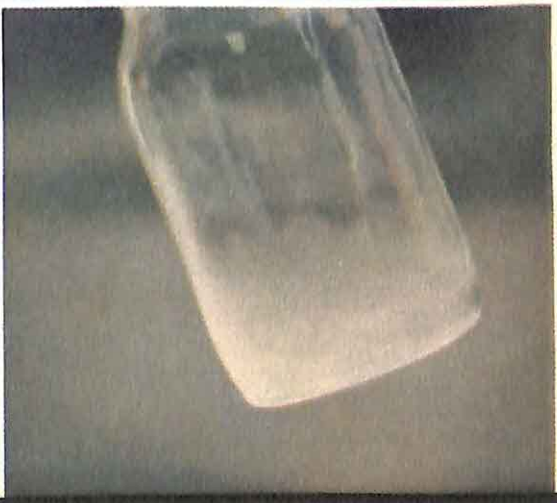
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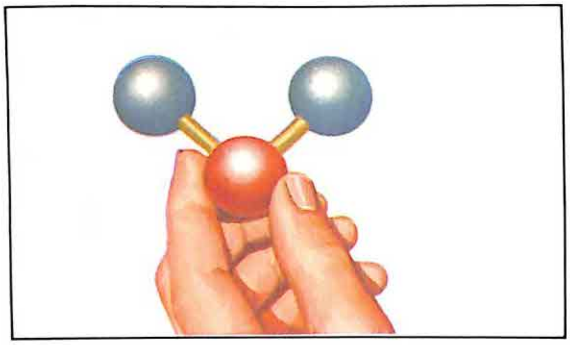
gathers, we can see the crowd. Let us imagine that a model of a molecule of water looks like this. ■ Then we can imagine that a drop of water might look like this. ●

When you put a drop of water in the glass chamber and the water disappears, here is what happens. A drop of water is a great crowd of water molecules. Some of these water molecules leave the crowd. They escape into the air. ▲ We say the water **evaporates.** The molecules of water mix with the air. As more and more water molecules leave, the drop gets smaller and smaller. In time all of the drop evaporates. All the water molecules go into the air.

Notice that all the water molecules are still inside the glass chamber. However, they are scattered in the air. They are far apart. The water has become an invisible gas. This invisible gas is **water vapor.** When you place the glass chamber in sunlight or near a warm radiator, the liquid water evaporates and becomes a gas—water vapor.

All the water molecules are still in the chamber, but they are no longer gathered together in a crowd. You cannot see them.

When you place the glass chamber in the refrigerator, the opposite happens. Water molecules come back out



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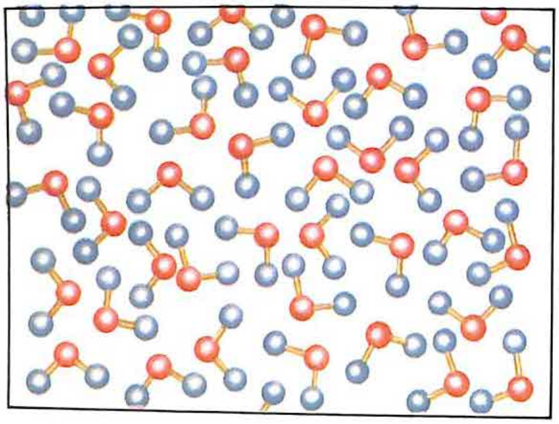

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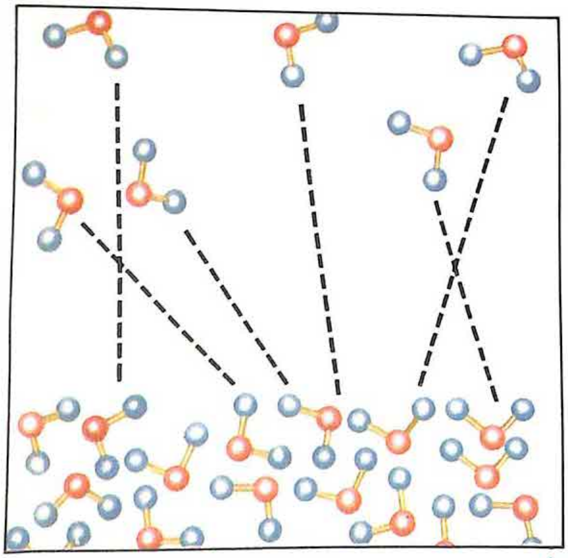

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of the air and gather on the glass. They stop being a gas—water vapor. They become a liquid again—water. You can see the water. You can also taste it if you want to. Water molecules have come back together.

Water, it seems, can become an invisible gas, called water vapor. And this invisible gas can become visible water again. This you learned in your investigation. It will always happen every time you try it.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Water vapor is a
   a. liquid b. gas
2. When water evaporates, it turns into invisible
   a. water vapor b. air
3. Compared with water, the molecules in water vapor are
   a. closer together b. farther apart

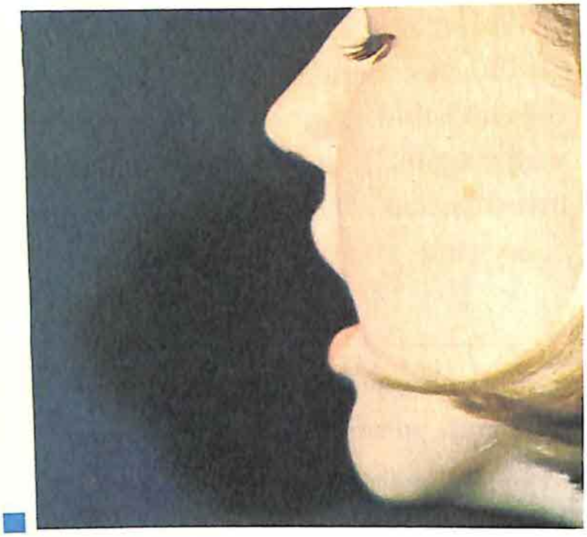
USING WHAT YOU KNOW

1. A drop of water is placed in an *open* glass. The drop disappears after a time. What has happened to the molecules of water?

2. A drop of perfume on a plate soon disappears, but the perfume can be smelled in the air. What has happened?

ON YOUR OWN

Try to demonstrate that water evaporates faster in moving air than in still air.



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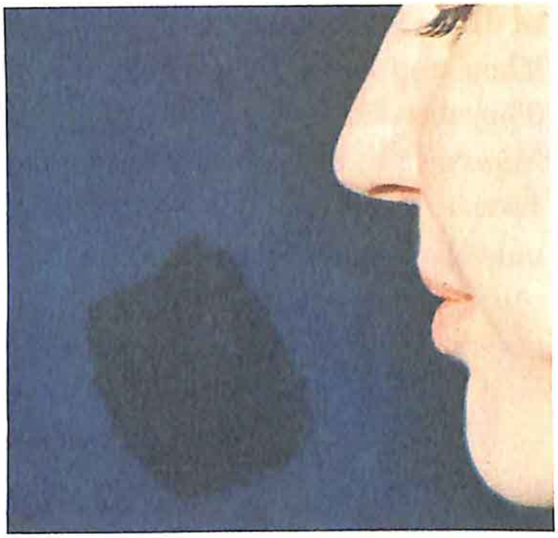

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2. Water from the Air

Go to a chalkboard or a mirror and breathe on it. A damp spot appears. It is made by water in your breath. ■ Watch what happens to the spot: it disappears. ● It evaporates as the molecules of water that make the spot fly out into the air. As it evaporates, liquid water changes to invisible gas —water vapor.

The same thing happens to drops of water, to puddles, to ponds, and to oceans. Molecules of water fly into the air from them. Since this is so, there must be many water molecules in the air around us. Can we catch some of them? Can we get some water from the air? See for yourself. Try the investigation on the opposite page.

Water in the Air

Suddenly, water appears on the outside of a shiny can. There is water inside the can, cold water. But the water on the outside does not come from inside the can. The water cannot pass through the side of the can.

The water that gathers on the outside of the shiny can *comes from the air* around the can. We have taken water from the air. Let us see how it happens. Perhaps you can make a good guess. Try to reason it out from what you know about molecules and how they behave.

When some ice is put into the can, the water in the can gets colder and colder. As the water gets colder, the can gets colder. And as the can gets colder, the air touching the can gets colder.

AN INVESTIGATION into Getting Water from the Air

Needed: an empty shiny can, ice, water

Remove the paper label from an empty can by soaking it. The surface of the can should be shiny. Dry the can. ■

Put water in the can until it is about half full. Do not get water on the outside of the can—keep the outside dry.

Now add some ice to the water in the can. As the ice is cooling the water, watch the shiny surface of the can carefully. ●

In a few moments, what happens to the shiny surface? Here is what happened in one trial. ▲

Touch the dull surface with your finger. ◆ It is water. Where did the water come from?

Additional Investigation: Predict what will happen to the water on the outside of the can when the water inside warms up again. Let the can of water warm up to test your prediction.

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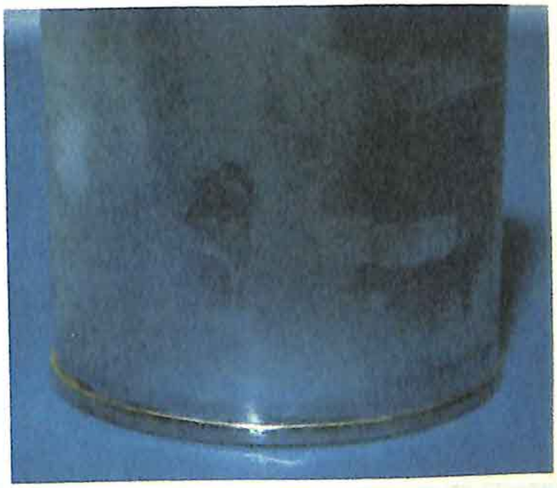
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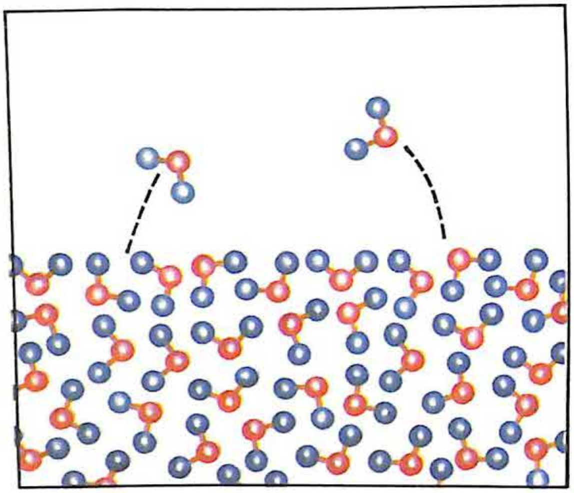
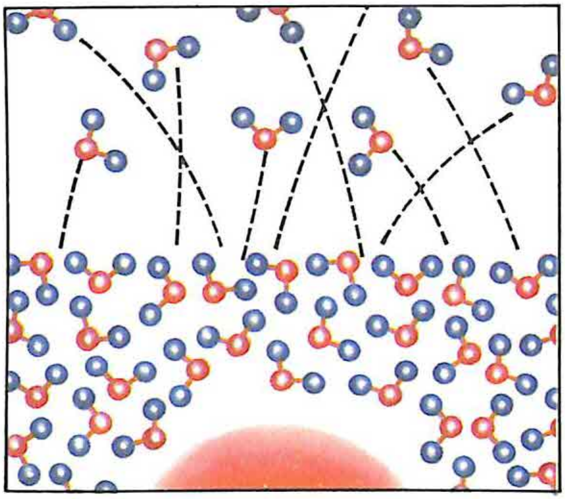




In the air around the can, there are molecules of water vapor. *As the air gets colder, it cannot hold so many molecules of water vapor.* Warm air can hold many molecules of water vapor. Cold air can hold only a few. So as the air next to the can gets colder, the air has to give up some of its water vapor molecules.

What happens to these water vapor molecules that are being pushed out of the air? The water vapor molecules become liquid water on the cold shiny side of the can.

You know what happens when a sponge full of water is squeezed. It cannot hold so much water. Some of the water comes out. When air is cooled, it cannot hold so much water vapor. Some of the water vapor comes out. The water vapor that comes out turns to liquid water.

When water vapor becomes liquid water, we say that the water vapor **condenses** (kon·DEN·sez). The water vapor condensed in the air around the cold, shiny can. As the air cooled, the water vapor in it condensed on the can and made a layer of water. **Condensation** took place.

Here is another example of condensation. When you breathe out, you breathe out water vapor. When you breathe on a chalkboard, the water vapor in your breath condenses on the board. This condensation makes a thin layer of water on the board.

Why does the water vapor in your breath condense on a chalkboard? The chalkboard is cooler than the warm air you breathe out. When the warm air touches the chalkboard, the air is cooled. Some of the water vapor condenses on the chalkboard.

There is water in the air around us. It got there by evaporation. We got back some of it by condensation.

It Takes Energy

Wet a finger. Hold it up and move it about in the air. Do you observe two things happening to your wet finger?

The finger dries, of course. The water evaporates. The water molecules fly off and become water vapor. There is something else, however. Did you notice that your finger becomes cool?

As the water evaporates, your finger becomes cool. Your finger becomes cool because it is *losing heat*. What is it losing heat to? Your finger is losing heat to the water that is evaporating. Evaporation takes heat energy. To go on, evaporation has to have heat energy. The water evaporating from your finger takes heat from your finger.

What is one way of getting water to evaporate quickly? Heat the water. Boiling water evaporates much more quickly than ice water. Warm water evaporates more quickly than cold water. Warm water has more heat energy than cold water. Evaporation takes heat energy.

Molecules are always on the move. Heat energy makes molecules move about more. The molecules can jump into the air faster and higher. More molecules can escape into the air. ■ Evaporation goes faster.

If some heat energy is taken away from these moving molecules, what will happen? The molecules will slow down. If enough heat energy is taken away, then water vapor molecules will slow down enough to become water again. The water vapor will condense. To make water vapor condense into water, heat energy must be taken away from the water vapor.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Which one of these can hold more molecules of water?
   a. warm air b. cold air
2. Water that is changing from liquid to gas is
   a. evaporating b. condensing

3. Water vapor that is cooled enough
   a. evaporates   b. condenses

4. To evaporate, water needs
   a. heat energy   b. no energy

5. Heat energy makes molecules of water
   a. move faster   b. slow down

USING WHAT YOU KNOW 1. Fanning makes water on our skin evaporate. Why does fanning cool us?

2. Where does the water that collects on the outside of a glass of ice water come from? Why?

ON YOUR OWN You know that water condenses on a can filled with ice. The temperature at which this condensation happens is called the *dew point.*

Is the dew point lower on a muggy day than on a dry day, or is it higher? How can you find out?

3. A Cloud Is Made

Have you ever watched clouds? Have you watched a cloud slowly change shape? Clouds seem to come in all shapes and sizes. Some look like feathers drifting across the sky. Some look like great lumps of cotton. Some are white, some are gray. Some are white on top and gray on the bottom. Some clouds make a gray roof over our heads that shuts out the Sun. Sometimes there are no clouds at all.

Some clouds come with sunlight and warm weather. Some come with sunlight and cold weather. Some come with rain, some come with snow. Where do clouds come from? Where do they go? What are they made of? Let us think a bit first.

Pushing Molecules Apart

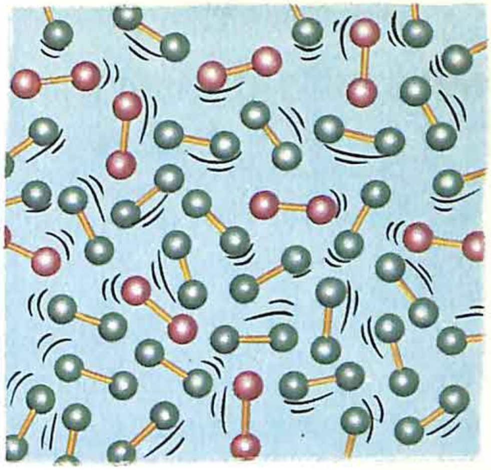
If you warm a balloon, it gets bigger. If you cool a balloon, it gets smaller. Why? Because of the *air* inside the balloon.

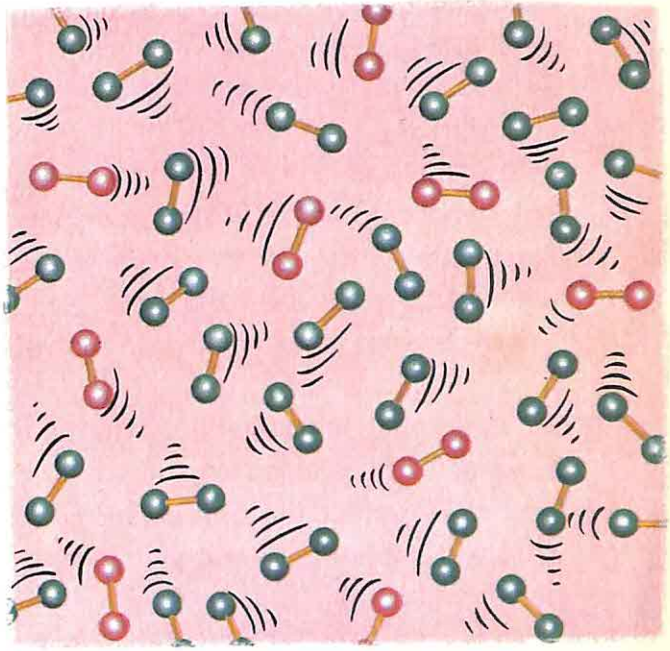
When air is warmed, it swells up. It takes up more space. We say that the air **expands.** When a balloon is warmed, the air inside the balloon is warmed. The air inside the balloon expands. The balloon gets bigger.

Air expands when it is heated. Remember that air is made up of molecules of different substances. These molecules are always on the move, bumping into each other, bouncing off each other. When they are heated, the molecules move faster, bump against each other harder, and push each other farther apart. ■

Air expands when it is heated because the molecules in the air move farther apart. What do you suppose happens when air is cooled, then? Just the opposite happens. When heat energy is taken away from air, the molecules slow down. They come closer together. They do not take up as much room as they did. Air takes up less space when it is cooled. We say that the air **contracts.**

When a balloon is cooled, the air in the balloon has heat energy taken away from it. The air contracts.





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Air expands when heated and contracts when cooled. This is one step toward the making of a cloud. Knowing how air expands and contracts helps us to understand how clouds form. You can begin to find out more about clouds by doing the investigation on the next page.

AN INVESTIGATION into Warmed Air

Needed: two balloons, two pans, a bottle, a tape measure, hot and cold water

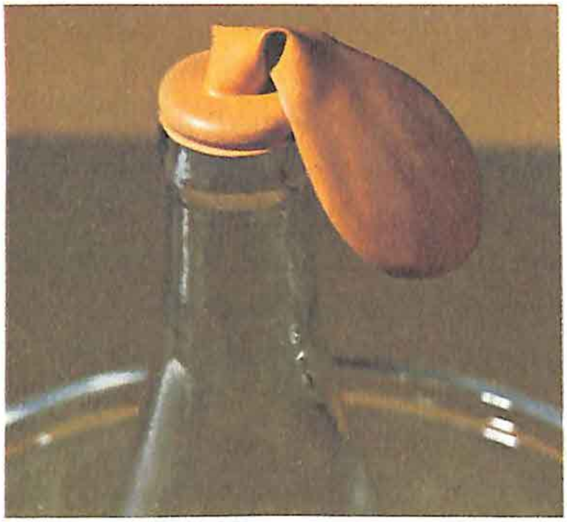
Put a few drops of water in the bottle. Put the balloon over the mouth of the bottle, like this. ■

Put some very hot water in a pan. Put the bottle in the water. ● What happens to the balloon? Here is what happened in one trial. ▲

How do you explain what happens? Put some cold water in the other pan. Place the bottle in the cold water. What happens to the balloon?

Here is what happened in one trial. ◆

An Additional Investigation: What will happen to the balloon on the bottle if the bottle is placed in sunlight? Predict what will happen and test your prediction.



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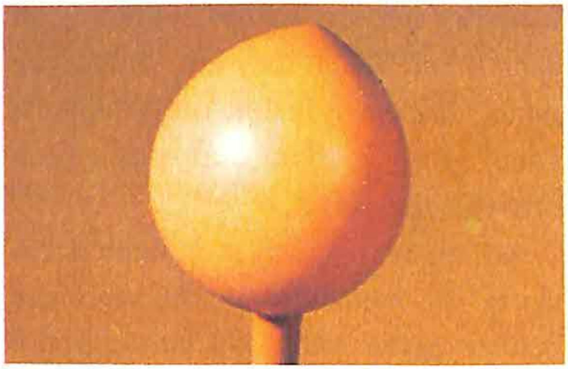

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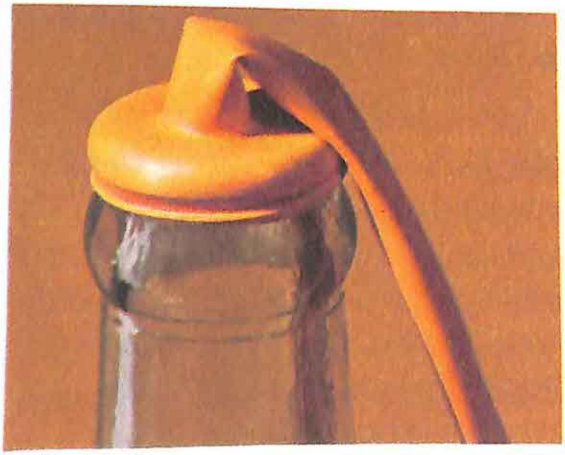

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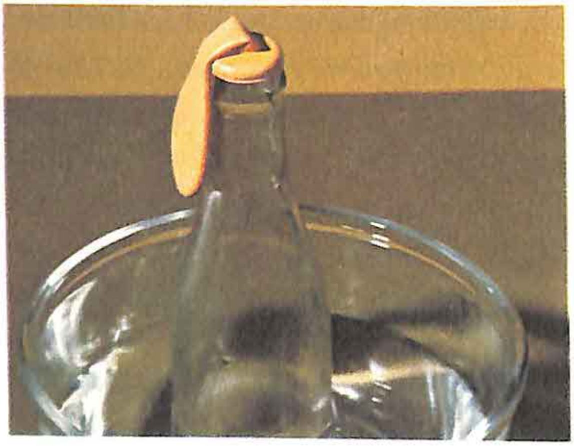

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The Weight of Warm Air

Let us do an imaginary investigation. We will take two boxes that are really empty. They do not even have air in them. We will fill one with warm air and the other with cold air.

Which box has more molecules in it? Cold air molecules are closer together than warm air molecules. Then there must be more molecules in the box of cold air.

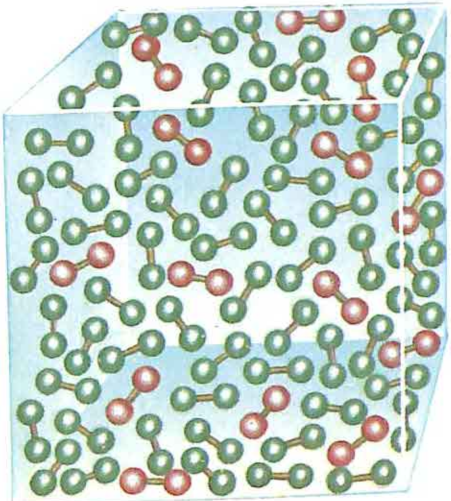
Which box weighs less, the one with the warm air or the one with the cold air? The box with fewer molecules in it weighs less, certainly. The box with the warm air weighs less than the box with the cold air. ●

Warm air is lighter than cold air. So warm air that is surrounded by cold air rises. You have seen evidence of this many times. Smoke rises from a fire, doesn't it? Smoke is carried by warm air that is rising because the warm air is lighter than the cooler air around it. ■

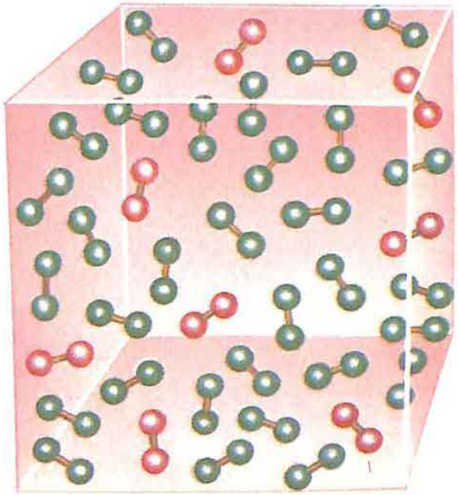
■

Warm air rises. This is another step toward the making of a cloud.

●



cold air



warm air

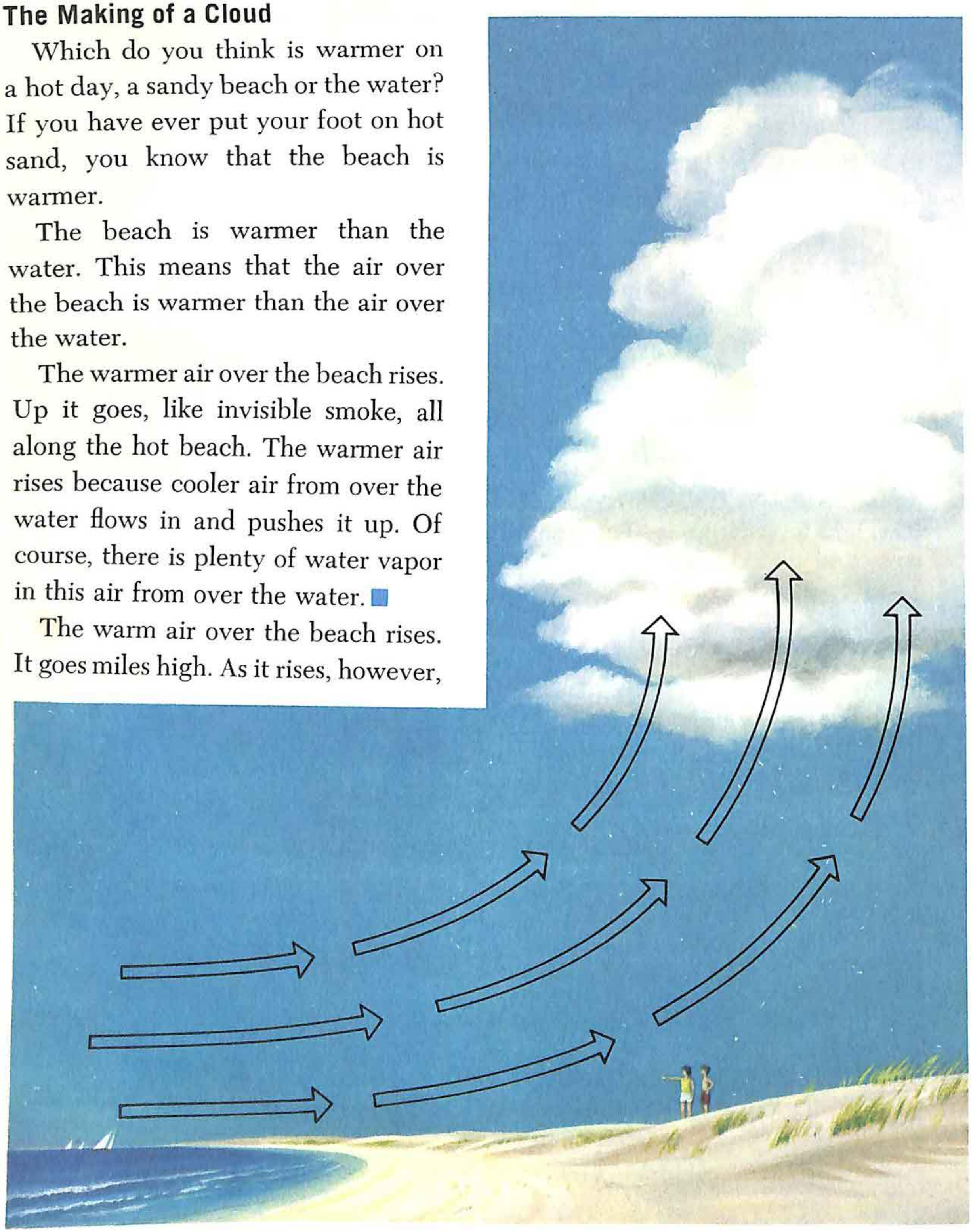
The Making of a Cloud

Which do you think is warmer on a hot day, a sandy beach or the water? If you have ever put your foot on hot sand, you know that the beach is warmer.

The beach is warmer than the water. This means that the air over the beach is warmer than the air over the water.

The warmer air over the beach rises. Up it goes, like invisible smoke, all along the hot beach. The warmer air rises because cooler air from over the water flows in and pushes it up. Of course, there is plenty of water vapor in this air from over the water. ■

The warm air over the beach rises. It goes miles high. As it rises, however,



something happens to it. *The rising air cools.* The higher the rising air goes, the colder it gets.

Cold air cannot hold as much water vapor as warm air. The water vapor in this rising, cooling air condenses. It turns to water. The water vapor turns into tiny droplets of water, each one smaller than the point of a pin. These droplets form a cloud. A cloud is made up of tiny droplets of water, hanging in the air. A cloud is made from condensed water vapor.

You might wonder why these water droplets stay up in the sky. Remember that they are in rising air. The droplets are so small and light that the rising air can keep them from falling. Indeed, the rising air may sweep them up higher and build a towering cloud.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

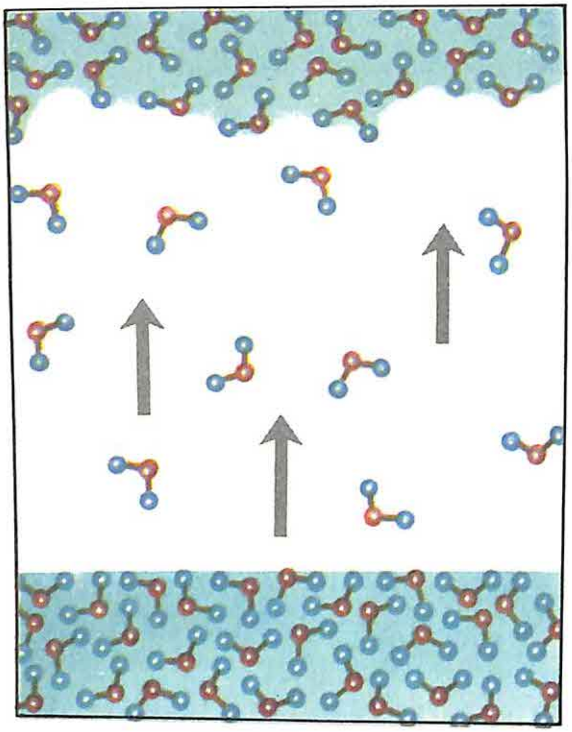
1. Air that is heated
   a. contracts b. expands
2. Warm air that is surrounded by cold air
   a. falls b. rises
3. As air rises into the sky, the air gets
   a. colder b. warmer
4. A cloud is formed when water vapor in rising air
   a. condenses b. evaporates

USING WHAT YOU KNOW

1. Why don't clouds form easily over a desert?

2. On a damp day the smoke from a chimney may not rise far. Why?

ON YOUR OWN How many kinds of clouds do you think there are? Look up "clouds" in an encyclopedia and see.



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4. A Drop of Rain

What happens in a cloud to make it rain?

A cloud is a collection of tiny droplets of water. They are so tiny that it would take about one hundred of them side by side to reach across the head of a pin. If you have ever walked through fog, you know how the droplets in a cloud feel. Fog is a cloud down on the ground.

It takes about a million cloud droplets to make one raindrop. How do they get together? The investigation on the opposite page will suggest part of the answer.

Inside the Glass Chamber

What is happening in the glass chamber in the investigation? Something is happening, certainly. At the beginning of the investigation, the upper glass is clear. Little by little, a film of moisture collects on the clear glass. Water is collecting on the glass. Water is traveling from the bottom of the chamber to the top of the chamber, somehow.

How does water get from the bottom to the top of the glass chamber? At the bottom of the chamber, the water is evaporating. Water molecules are flying off the water. ■ They are becoming water vapor. Very soon the air in the chamber is full of water vapor.

At the top of the chamber, though, water vapor is condensing. The water vapor is turning into tiny droplets of water on the sides of the glass and is making the glass cloudy. The air at the top of the glass is cooler than the air at the bottom. So the water vapor at the top condenses. It forms tiny droplets.

Isn't this how a cloud is made? In a cloud, the air becomes cooler as it rises. In the glass chamber, the air cools as it reaches the top because it loses heat to the cooler part of the glass. In both the cloud and the glass

AN INVESTIGATION into a Glass of Water

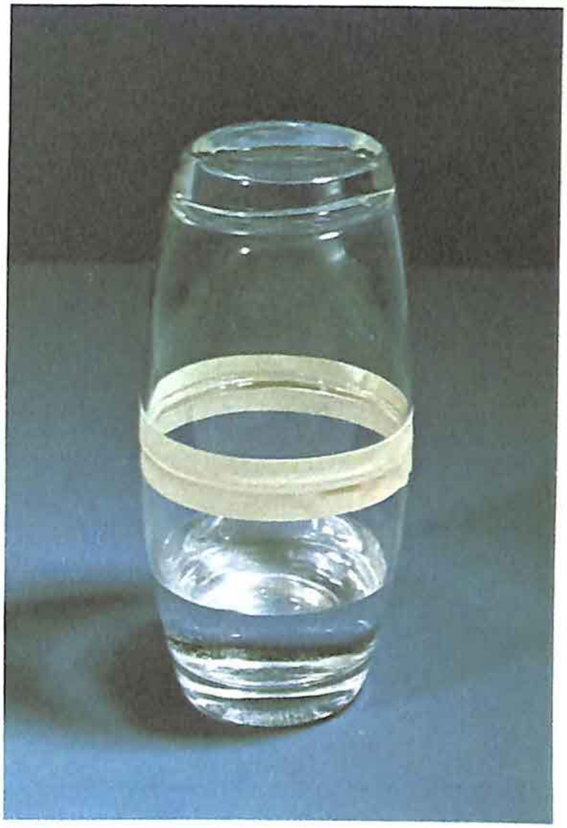
Needed: two glasses, sticky tape, water

Pour about an inch of water into one of the glasses. Tape the other glass on top of the first glass with the sticky tape, like this. ■ Make a good, tight seal with the tape so that nothing can get in or out of the glasses. Now you have a sealed glass chamber with water and air in it.

Put the sealed glass chamber on a warm radiator or in a warm place. Notice that the upper part of the chamber is clear. ●

Look at the chamber from time to time during the next hour or so. Watch what happens to the upper part. Here is what happened in one trial. ▲

How can this be explained?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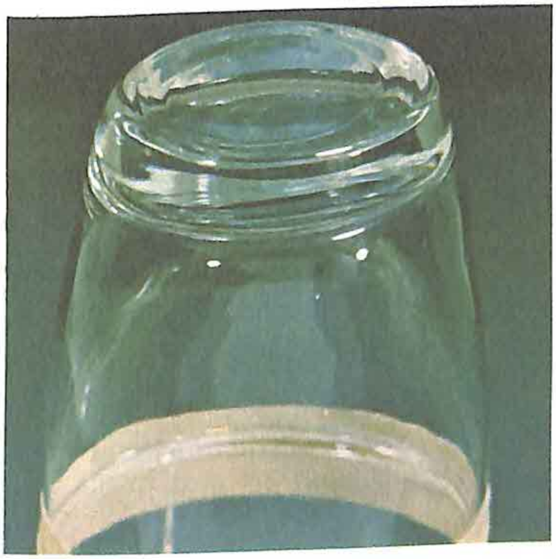
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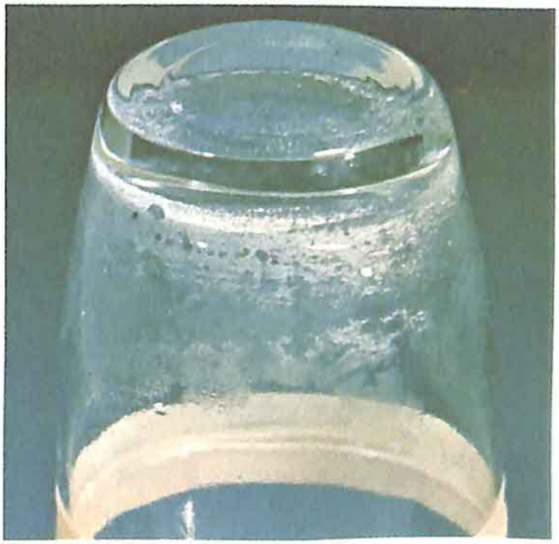
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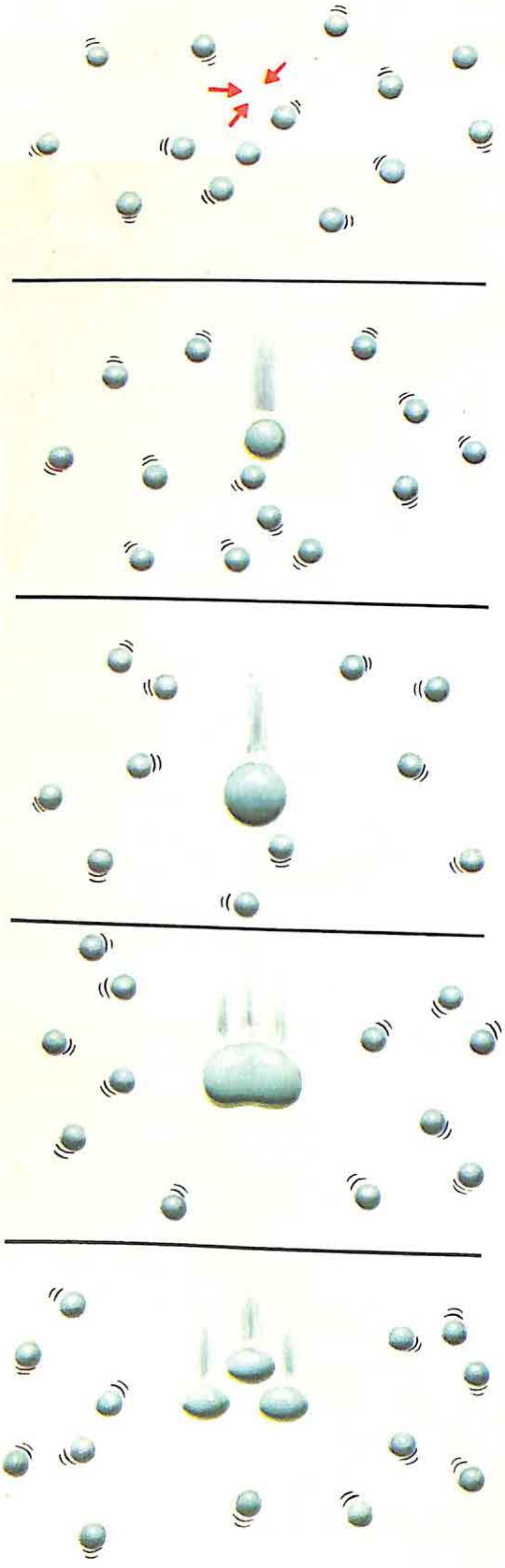


chamber, the same things happen. Air with water vapor in it rises and cools. The water vapor condenses into droplets. In the cloud, the droplets float in the air. In the glass chamber, the droplets gather on the glass to form larger drops.

The Droplets Grow

Something else happens in the glass chamber. At first the upper glass is only cloudy. There is only the thinnest layer of water on it. The droplets are too tiny to be seen. As time passes, however, more water condenses on the glass. You can begin to see drops of water on the glass. The drops get larger as the tiny droplets too small to be seen gather together to make bigger drops that can be seen.

Something like this happens in a cloud, too. The tiny droplets moving about in the rising air come together to make larger droplets. The larger droplet is heavier than the small ones. It starts to fall. As the larger droplet falls, it collides (bumps into) with more small droplets. These collisions make a large droplet larger still. It becomes a raindrop.

That is not the end, however. The raindrop may have still more collisions as it falls. It may get still bigger, so big that it cannot go on as one raindrop. It breaks into smaller drops. Each of these smaller drops now has collisions with droplets, and starts growing. It is a kind of chain reaction. One drop leads to others, and others, and still others.

At last some drops fall out of the cloud and fall to the ground. It is raining.

Unfinished Business

There is another way in which cloud droplets may come together to make raindrops. The droplets may be carried so high by the rising air that they are turned to crystals of ice.

The air has to be very cold for this freezing to happen. These crystals of ice get larger and larger. As they get larger, they get heavier and begin to fall through the cloud.

As they fall, the crystals of ice get into warmer air. If the air is warm enough, they melt and become raindrops. If the air is not warm enough, the crystals fall to the ground without melting. "It's snowing!" we say.

Scientists used to think that this was the only way in which clouds made rain. Then they found out that many clouds make rain without being cold enough to freeze the cloud droplets. Now scientists think that the collision of droplets must be important. But there is some unfinished business here. Just how do the very first tiny droplets come together to make a drop? How can enough collisions happen? Scientists are not yet sure of the answers to these questions.

Scientists are working on them, though.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A fog, like a cloud, is made up of
   a. water vapor b. water droplets
2. To form a cloud, water vapor is
   a. evaporated b. condensed
3. Raindrops are formed by small water droplets
   a. colliding b. separating

ON YOUR OWN Cloud seeding is supposed to help in forming rain. Do some library research. Find out how cloud seeding works. Does it produce rain?

5. Rivers in the Sea

Do you remember putting water in the bottom of a glass some time ago? The water disappeared. Where is that water now? Of course it evaporated. Its molecules flew off into the air and became a gas—water vapor. Where are those molecules now?

Many things may have happened to them. Perhaps those same molecules are still water vapor but are now being carried by the wind to far-off lands. Perhaps those molecules have condensed. Perhaps they are part of a cloud hundreds of miles away.■ Or they may be falling somewhere as raindrops. Perhaps they have fallen somewhere on a mountain or in a valley. It may be that they are flowing down a river to the sea. They may be moving along in a great river in the sea. Yes, there are great rivers, or **currents,** in the sea. For example, there is one current in the sea called the Gulf Stream. Its light-colored water is warmer than the darker water through which it flows. It flows through the darker water like a great river, many miles wide.

What makes this warm current in the sea? The investigation on the opposite page will give an important clue to the answer.

■

AN INVESTIGATION into Mixing Cold and Warm Water

Needed: two large jars, two small bottles, ice water, warm water, red and blue ink

Fill one large jar and one small bottle with ice water. Add blue ink to the small bottle to color the water.

Fill the other large jar and small bottle with warm water. Add a few drops of red ink to the small bottle of warm water.

Take the bottle of blue ice water. Hold it just over the jar of warm water. ■ Slowly tilt the bottle. Let the cold blue water flow out into the warm water. ● What happens to the cold water in the warm water?

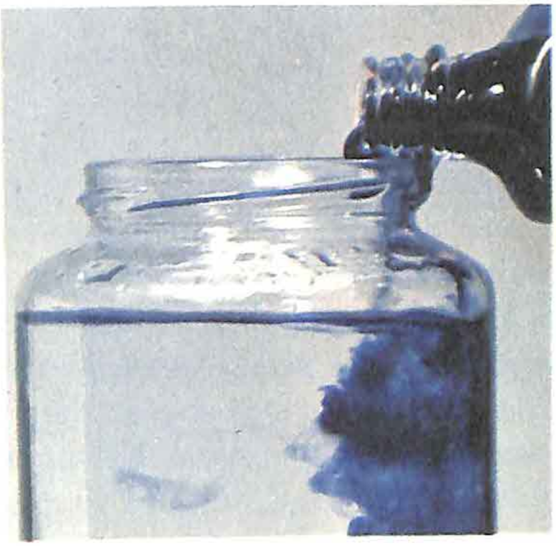
Here is what happened in one trial. ▲

In the same way, empty the bottle of warm red water into the jar of cold water. What happens to warm water in the cold water? Here is what happened in one trial. ◆

How can you explain what happened?

Additional Investigation: Try the same investigation, using salt water. Are the results the same as in fresh water?

■



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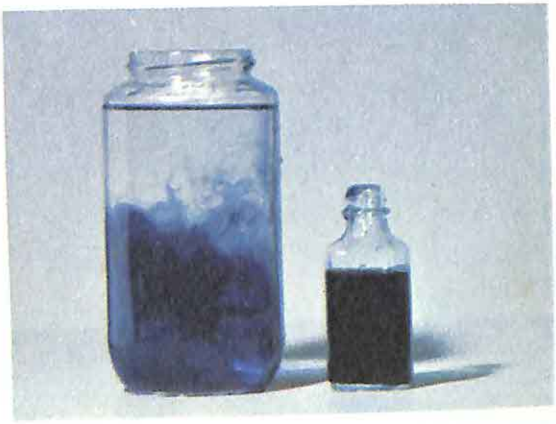

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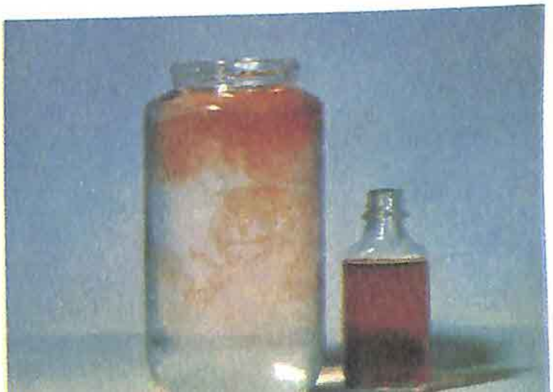

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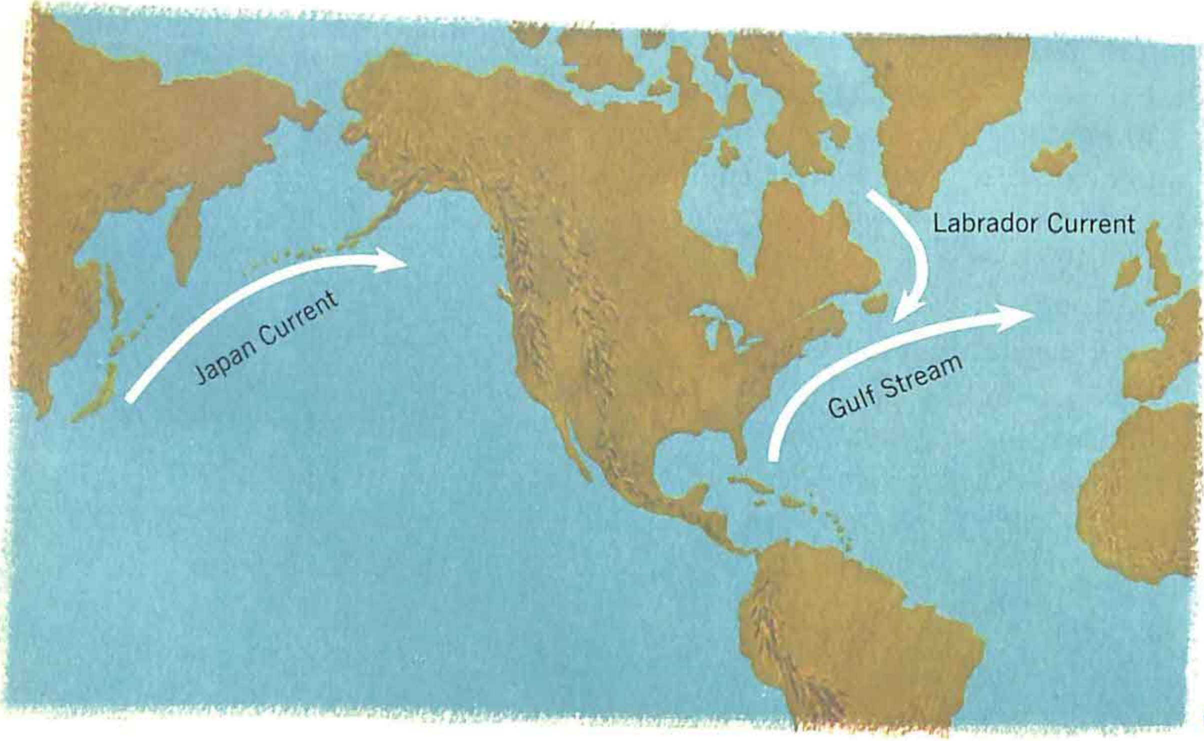
Sink or Float

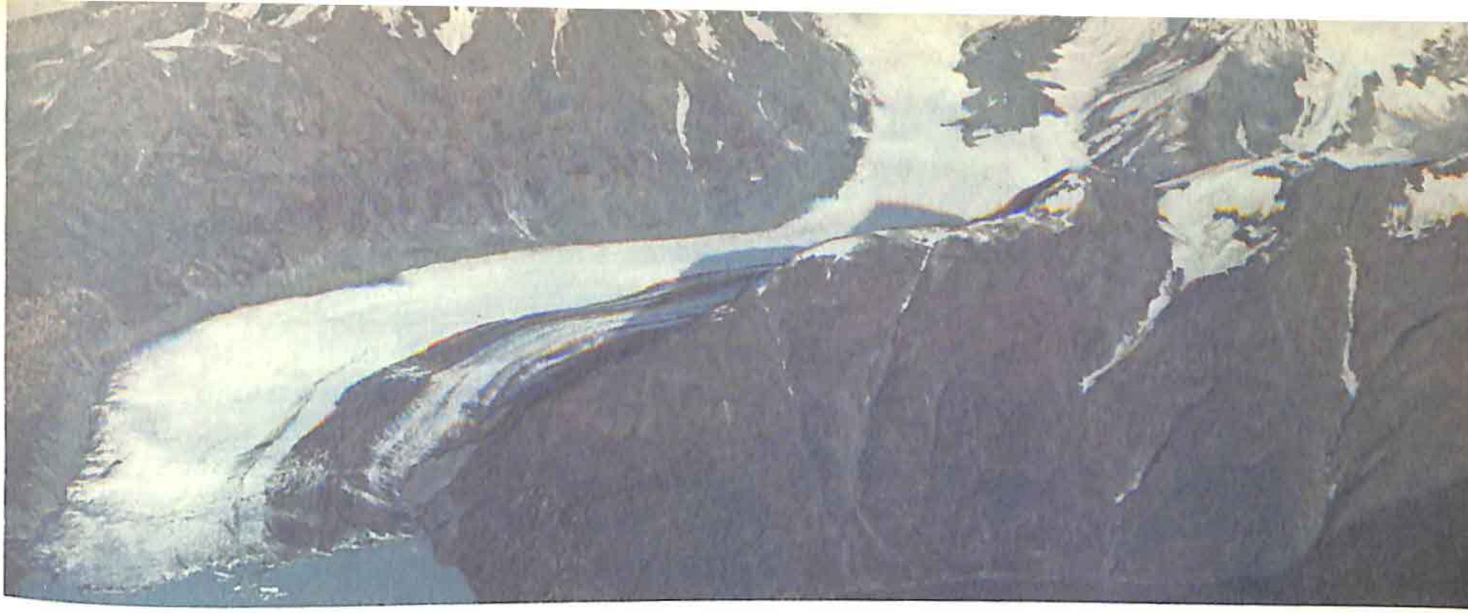
When cold water is placed in warm water, the cold water sinks. When warm water is placed in cold water, the warm water rises.

Does this remind you of something? When warm air is in cold air, the warm air rises. Cold air sinks in warm air. This happens because warm air is lighter than cold air. The molecules of warm air are farther apart than molecules of cold air. This makes warm air lighter than cold air.

Warm water is lighter than cold water, for the same reason. Warm water floats on top of cold water, then, if they are not mixed. The warm water in the Gulf Stream that has come from the Gulf of Mexico floats on the cold water below it.

There is another reason why the water in the Gulf Stream is light and floats. Much rain falls in the Gulf of





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Mexico. Rainwater is lighter than seawater. Seawater contains many **dissolved** substances, which makes it heavy. Here is the amount of dissolved substances in a pailful of seawater.■ Compare it with the amount of dissolved substances in a pailful of rainwater.■

We saw that the light, warm water in the Gulf of Mexico does not stay there. It leaves the Gulf and flows along our Atlantic coast.●

Why does the Gulf Stream flow? The water is moved by wind. Wind blowing over water moves the top layer of water along.

Scientists are not yet sure just how wind moves water along, although they know that it happens. The fact that the Earth is turning while the water is being moved along affects the path of the Gulf Stream too. It is not a simple problem, but wind is the main mover of the warm Gulf Stream.

A drop of rain that falls into the Gulf of Mexico may be carried into the Atlantic in this river of warm water. There are other currents in the sea that can carry a drop of water far. Notice the Japan Current.● It is warm water, like the Gulf Stream. The Japanese call it Kuroshio (kur-O·SHE·O). Kuroshio means "black stream." This warm water is darker than the cold water around it.

The Labrador Current brings cold water from the north. It may bring icebergs as well. An iceberg may come from another kind of river, a river of ice called a **glacier** (GLAY·shur). Here is a glacier in Alaska.▲ This glacier is a stream of ice that is slowly moving down this valley to the sea. The glacier is fed by snow in the mountains. As the river of ice reaches the sea, pieces of ice break off and float in the water. They are icebergs, which are slowly carried out to sea by ocean currents. In time they melt and turn to water.

The molecules of the drop of water you evaporated a while ago may be sliding down to the sea in a glacier, some time in the future. Perhaps they will become part of Kuroshio. Perhaps they are now part of the water vapor in the air you are taking into your lungs.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Warm water that is in cold water
   a. rises b. falls
2. Compared with rainwater, seawater is
   a. lighter b. heavier
3. A glacier is a slow-moving river of
   a. water b. ice
4. The Gulf Stream is a warm current that moves on the
   a. top of the sea b. bottom of the sea
5. The Gulf Stream is moved by the
   a. wind b. water

USING WHAT YOU KNOW

The Kuroshio, a current, probably has less salt in it than does the sea around it. Why?

6. The Water We Eat

If you squeeze all the juice from an orange, most of what you squeeze out will be water. All plants have water in them. All animals have water in them. All living things are made partly of water.

Living things must have water. This means you, too. You need water every so often. You cannot store water like a camel or a cactus.

One way you get water is by eating it. When you eat most foods, whether they are vegetables, eggs, meat, milk, apples, or potatoes, you eat the water in them.

Most plants take in water, which then becomes part of them. When animals eat the plants, the animals get the water in the plant. The water that plants and animals get comes usually from drops of water which fall from clouds. Let us see how water gets into an apple.

The Water in an Apple

Apples have plenty of water in them. About four-fifths of an apple may be water. Other foods have water in them too, so you get some of the water you need by eating.

■

How did the water get into the apple? Let us follow another drop of water on a journey. This drop is one that falls near an apple tree in the middle of a summer shower.

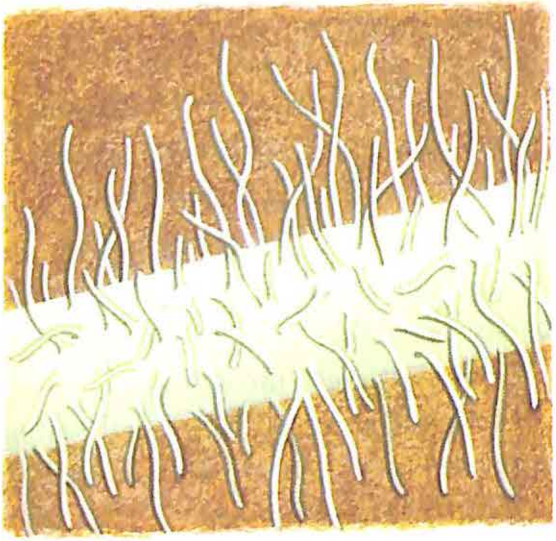
The drop falls on the ground beside the tree. The drop does not stay on the top of the soil, however. It sinks into the soil, and slowly flows downward through the tiny spaces in the soil.

As the water moves down through the soil, it meets substances that are in the soil. The water dissolves some of these substances. The dissolved substances are carried along with the water, as it moves downward. ■

A few inches below the ground, the water meets one of the small roots of the apple tree. ■ The root has rootlets growing from it. Each rootlet has millions of hairs growing on it called **root hairs.** Root hairs are the means by which a plant takes in water. The water that has traveled through the soil enters the root hairs. The dissolved substances in the water enter too, along with the water.

Then the water and the substances in it travel up into the branches and leaves and fruit of the tree, through water tubes. The tree uses the dissolved substances in the water to grow and to make apples. Thus water enters the apples.

Most plants get water much the same way as the apple tree does. This is true of vegetables as well as fruits. You eat the fruits or vegetables and the water that has become part of them.



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Is there much water in these foods? Let us find out for one of these foods from a growing plant, an apple. See for yourself. Try the investigation on the opposite page.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. The water we eat is found in
   a. most foods — b. plants only
2. Water entering the roots of plants
   a. has dissolved substances in it
   b. is pure rainwater
3. Most plants take in water through
   a. root hairs — b. water tubes

AN INVESTIGATION into Water We Eat

Needed: an apple, a knife, a scale, a plastic bag, a paper towel, a tray.

Weigh the apple on the scale. ■ Copy the table below into your notebook and enter the weight of the apple in it. Here is the weight in one trial.

Cut the apple into small pieces. It will dry out more quickly this way. Put the pieces of apple on the paper towel on the tray. Place the tray in sunlight on a windowsill. ● Leave it there for several days. Water will evaporate from the pieces of apple.

Weigh the dried-out pieces of apple. ▲ Enter the weight in your table. Here is the weight in one trial. Calculate the weight of water lost by the apple.

Weight of apple ______

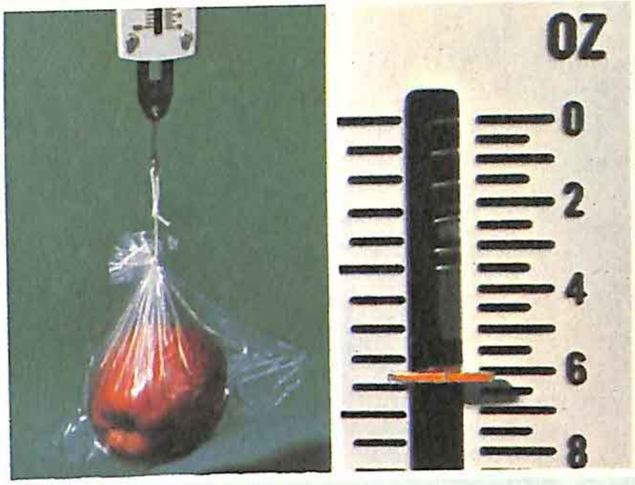
Weight of apple after drying ______

Weight lost by apple ______

Weight of water in apple ______

Could this investigation have been done differently? Was the piece of apple really dry?

Additional Investigation: Find out how much water a potato has.



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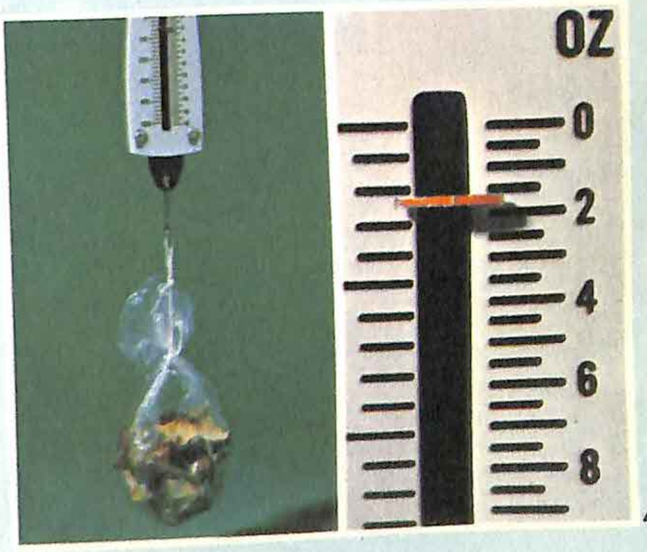

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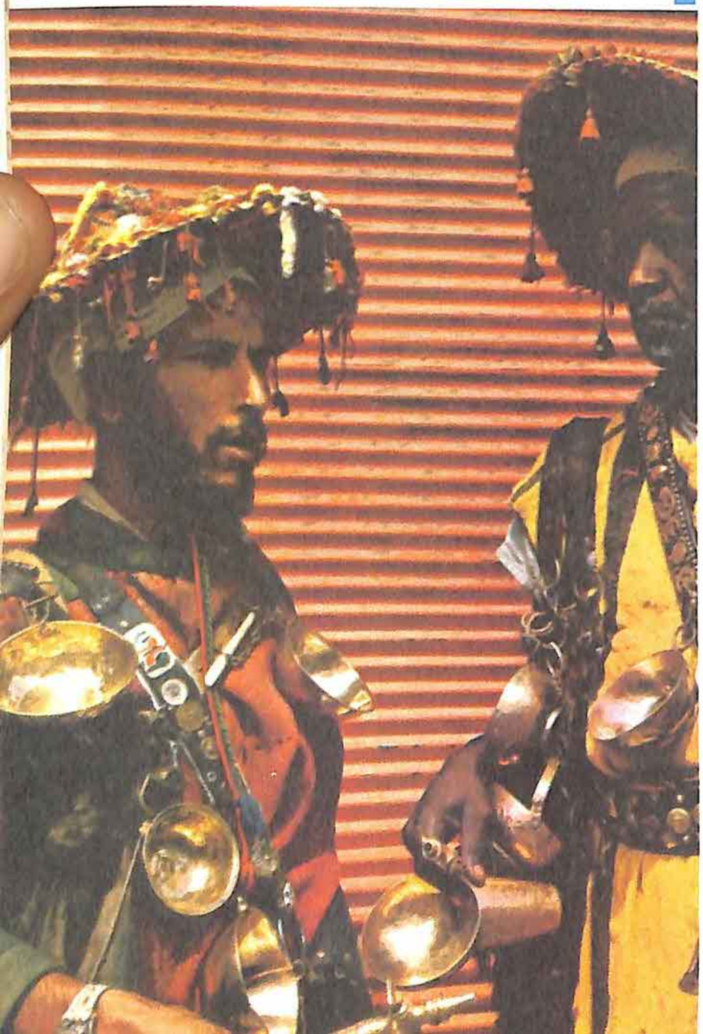
USING WHAT YOU KNOW How much water do growing boys and girls need? Some library research will help, or perhaps you know a doctor whom you can interview.

7. The Water We Drink

Here is a strange sight to most of us. These men are water carriers. ■ They sell drinking water. In their country, Morocco, water is so scarce that it can be sold like this.

When we are thirsty, we can go to a faucet or a well and drink as much as we want. We bathe, and we water growing plants. Each of us has to drink from six to eight glasses of water every day, besides the water we eat. Without water, we could not live. Without water, all plants and animals would die, sooner or later. Our water supply is most important. How do we get water?



Of course, water falls as rain and fills our rivers and lakes. Yet the water we drink is clean and pure. How do we clean our water? Try one way of cleaning water yourself, in the investigation on the opposite page.

Making Water Clean and Pure

The water that comes from a faucet in a big city like New York or Los Angeles comes from many miles away. New York's water supply begins with rain that falls in mountains many miles away from the city. Some of the water in Los Angeles comes from mountains in other states. As rain falls, the streams and rivers over a large area of land collect the rain. The area in which the streams and rivers collect the rain and snow is

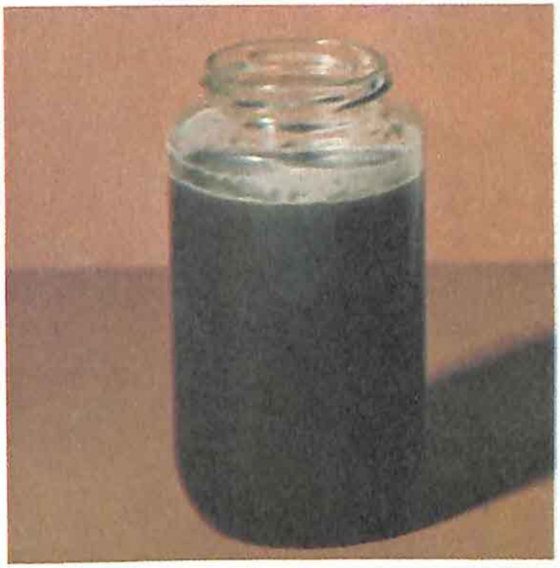
Making a Model: A Water-Purifying Plant

Needed: a funnel, sand, cotton, about half an inch of garden soil in a quart jar, another clean quart jar

Add about a quart of water to the jar with soil in it, and shake it up so that the water is full of soil particles. ■ Let the water stand for a while. What happens to the soil particles? ● What happens to the water as the particles settle to the bottom? Settling is one way of cleaning water.

Place some cotton in the funnel, and put a layer of sand about an inch deep over the cotton. ▲ Put the funnel in the clean jar. Gently pour some water from the settling jar into the funnel. What happens to the water in the funnel? ◆

One way of cleaning water is to pass it through a filter of sand. The holes between the particles of sand are very small. Particles of soil are filtered out of the water passing through the sand.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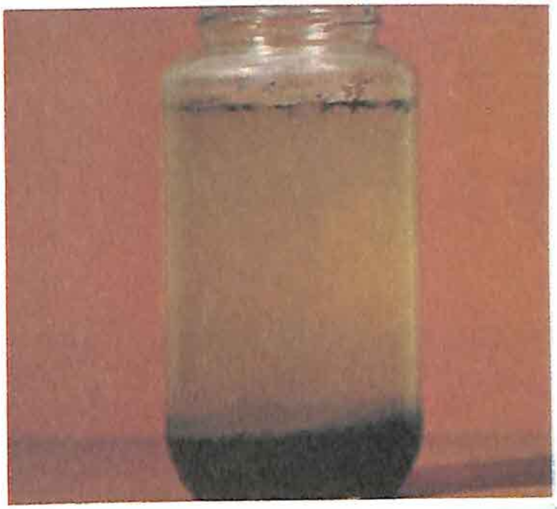
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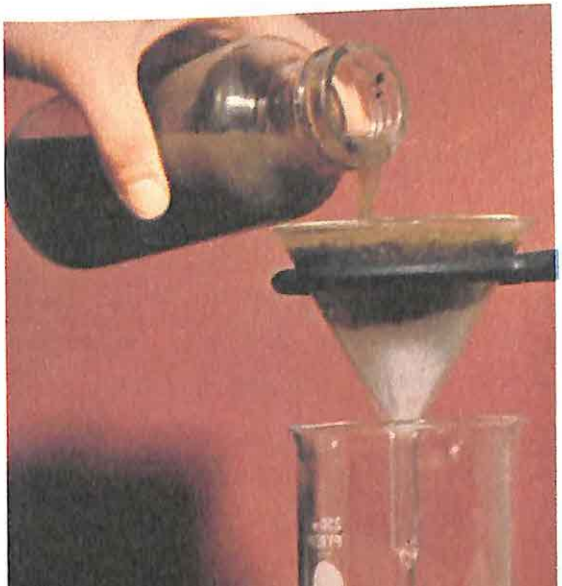
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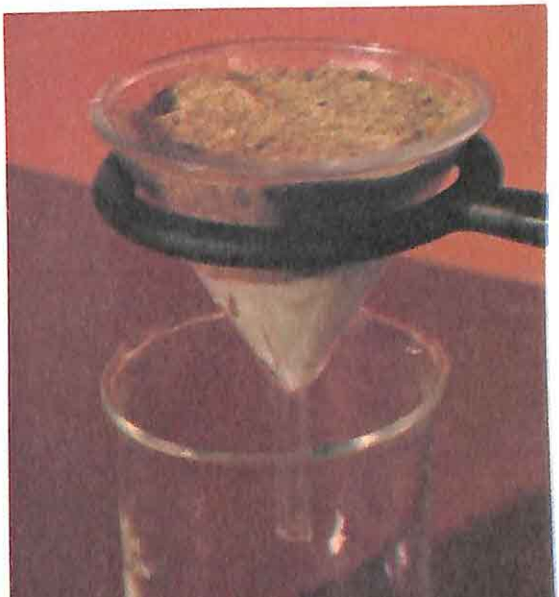
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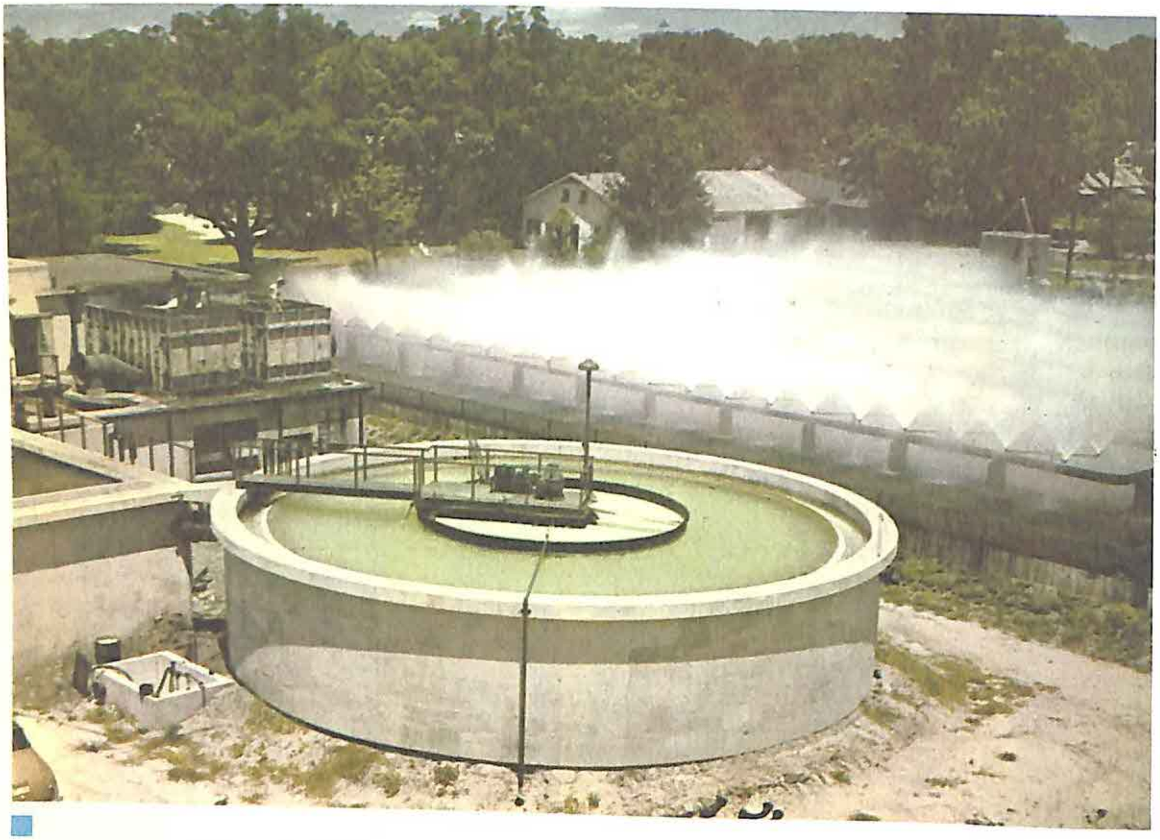

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called a **watershed.** Sometimes dams are built in a watershed, and the water is stored in **reservoirs.**

The water in a reservoir does not move much, so some of the particles of soil and rock in the water have a chance to settle to the bottom. Then the water goes to a purifying plant.

In the purifying plant, the water is placed in a settling tank. ■ Substances are added to the water to make particles settle more quickly. Then the water is filtered through layers of sand. Now the water looks clean, but in it there may still be tiny invisible plants called **bacteria** that can make persons ill. So the water is sprayed into the air. Bacteria will be killed and the toxic gases will be removed by the air. Finally, a tiny amount of chlorine gas is added to the water to kill any bacteria left. The water is then fit to drink.

On the Farm or Ranch

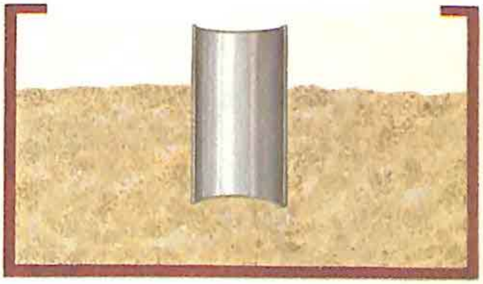
It is fine to have reservoirs and purifying plants, but this does not help the farmer or rancher who does not live near a city water supply. How does he get water? From a well, you might say. What kind of a well?

One kind of well depends on water that sinks into the soil. In making such a well, the farmer really digs a deep, round hole in the ground. He lines its walls with rock to keep the soil from falling in. Water seeps in through the bottom and fills part of the well. To understand how such a well works, make a model. Take an aquarium and fill it partly with sand. This will be the soil surrounding the well. Make a round hole in the soil. In it place a tin can from which both ends have been removed. This tin can open at both ends will be the sides of the well. Sink it into the soil but not to the bottom of the aquarium.●

What happens as water is poured on the soil? Try it first by filling the aquarium half way with water. How high does the water reach in the well? What happens as more water is added?

You can see that the water level in the well depends on the water level in the soil.

High rainfall, or a high supply of water in the soil, raises the water level, or **water table**, in the soil. Low rainfall, or a low supply of water in the soil, lowers the water table. This windmill pumps water from below the water table to the surface.▲

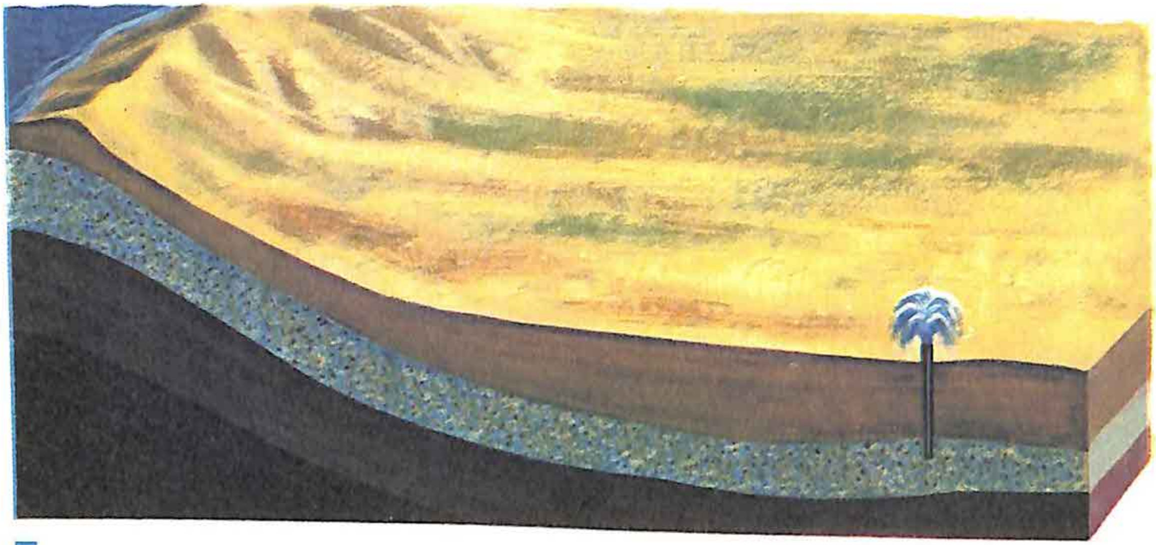


●

Such a well is risky, isn't it? It depends on rainfall, or underground water. In dry weather, the well may dry up.

Some types of rock can also hold water. Here is a rock layer that starts up in the hills and dips into the soil. You might think of it as a rock that holds water. Such a layer of rock

▲



■

may be deep in the earth.■ The well driller sinks a metal pipe into the layer. The water rises in the pipe.

Because these rock layers are often large, the water supply is often good.

A drop of water may start in a cloud. It may end in the most unexpected places. Drops of water have more adventurous journeys than you can imagine.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. The area in which the streams and rivers collect rainfall is called a
   a. reservoir
   b. watershed
2. Bacteria in water are killed by spraying the water in the air and adding
   a. particles
   b. chlorine
3. A water supply for some wells depends on the
   a. depth of the water table
   b. width of the well

USING WHAT YOU KNOW

1. Why is it important to keep watersheds clean and safe?
2. What kind of well must be dug in a dry region? Why?

8. The Main Concept: Around and Around

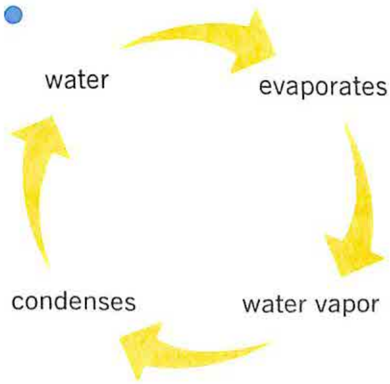
A drop of water makes many different journeys. It flows down a river into a lake. There it leaves the ground and rises into the air, as water vapor. Up rise its molecules. They make a cloud. Presently the water droplets in the cloud form drops. Down comes a raindrop. It falls on the ground, sinks into the soil, and meets the roots of a tree. It is taken into the tree, carried up the trunk, into a branch, and then into a leaf. It is given off into the air by the leaf, as water vapor.

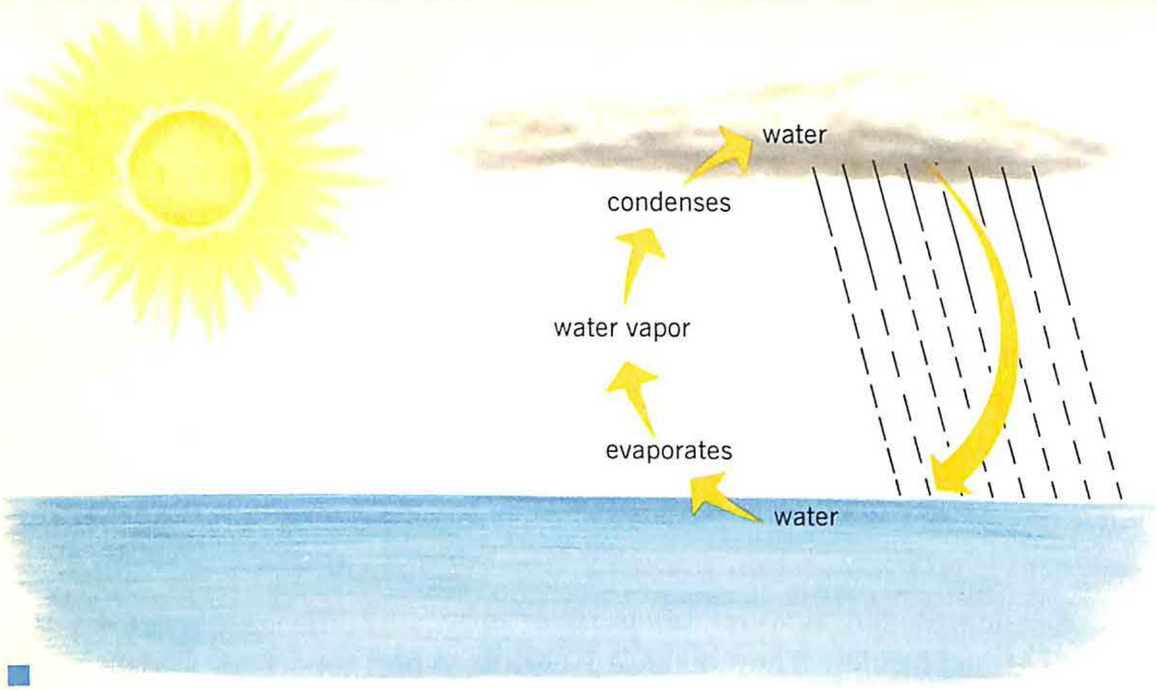
Again, the water vapor rises in the air. Again it forms cloud droplets. This time the droplets freeze and fall as snow. The snowflakes land on a cold mountaintop and slide down into a river of ice, a glacier. An iceberg breaks off the glacier, floats out to sea, and melts. The drop rises again to form another cloud.

This story has no end, has it? Molecules of water just go on traveling, on more different journeys than we can imagine.

Yet no matter how different the journeys that water molecules make, we know how they make them. Water evaporates. It turns to water vapor. The water vapor condenses and turns to water. Then the water evaporates. It turns to water vapor. Again the water vapor condenses and turns to water. This has no end either. Let us make a diagram that has no end, like this. ● No matter where you start, one happening leads to the next and the next and the next.

Since it goes around and around, this process is called a cycle. Since it is about water, it is called the **water cycle.**





The water cycle will fit any journey that a drop of water can make. Here is an example. ■

You can see that molecules of water are used over and over again in the water cycle.

Energy for the Cycle

It takes energy to make a motorcycle go. The energy is supplied by gasoline. It takes energy to make a bicycle go. You supply the energy yourself.

It takes energy to make the water cycle go. After all, a water molecule has weight, even if it is a very small weight. To lift any weight takes energy. To lift billions of water molecules into the air to make a cloud takes a great deal of energy. Where does the energy come from? The Sun.

The Sun is the source of energy for the water cycle. It is the Sun that provides the energy for evaporation. The Sun heats the molecules of water on the surface. The heat energy that comes from the Sun makes the water molecules move faster. They zig-zag about, and bump against each other more often. The molecules at the surface of the water leap higher into the air. Most of these leaping molecules fall back again. But as the water becomes warmer, more molecules escape and become water vapor.

The travels of every drop of water, its rising into the air and falling back to the earth, depend on the Sun and gravity.

Fixing the Main Concepts

TESTING YOURSELF Study these statements and choose the correct responses. Your study will help fix in your mind the main concepts of this section.

1. Water vapor is made up of
   a. molecules
   b. tiny droplets of water

2. Water vapor is a
   a. gas
   b. liquid

3. When water evaporates, it becomes
   a. visible
   b. invisible

4. When water vapor forms clouds, it
   a. evaporates
   b. condenses

5. One box is filled with water. Another box, the same size and weight, is filled with water vapor. Which of the two boxes weighs less?
   a. the box of water vapor
   b. the box of water

6. A box is filled with cold air. Another box, like the first, is filled with warm air. Which box weighs more?
   a. the box of warm air
   b. the box of cold air

7. Warm air surrounded by cold air
   a. rises
   b. sinks

8. Cold water surrounded by warm water
   a. rises
   b. sinks

9. The water you eat in plants comes to us through the
   a. soil
   b. reservoir

10. The water you drink is collected mainly in
   a. watersheds
   b. water-carrying rock

FOR YOUR READING

1. *Not Only for Ducks: The Story of Rain,* by Glenn O. Blough, published by McGraw-Hill, New York, 1954. A simple story of the water cycle is told in this book.

2. *Let's Look Under the City,* by Herman and Nina Schneider, published by William R. Scott, New York, 1954. A good book for the beginner who would like to see how a city gets its water. You will also find out how a city gets its gas and gets rid of its sewage.

3. *Everyday Weather and How It Works,* by Herman Schneider, published by McGraw-Hill, New York, 1961. This is a good book for learning about the tools the weather man uses. It also describes various kinds of weather.

ON YOUR OWN

What part of your refrigerator is coldest? What is your guess? If you remember what happened to warm and cold water when mixed, in the investigation on page 81, you may be able to make a good guess. Here is one way in which you can get some evidence to show how nearly right or wrong your guess is. A refrigerator, a thermometer, a watch, and pencil and paper are needed.

Make a copy of the diagram of the refrigerator shown on the next page. How many shelves are there in your refrigerator? On your diagram, put in as many places for thermometer readings as there are shelves.

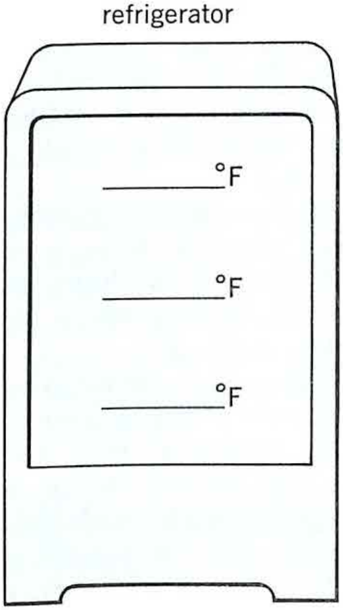
Put the thermometer on the top shelf of your refrigerator, in about the center. Close the refrigerator door quickly. Leave the thermometer inside for about three minutes.

Open the door quickly. Read the temperature on the thermometer at once. Record this temperature reading on your refrigerator diagram. Place the thermometer in the middle of the second shelf from the top, and close the door. Keep the refrigerator door closed for three minutes. Then, open the door, read the thermometer, record the reading, move the thermometer down a shelf, and close the door again.

Don't let the thermometer touch the side of the refrigerator. Don't put the thermometer in a container.

In this way, you can obtain some evidence of the temperature at different levels in your refrigerator. Does the evidence confirm your guess about which part of the refrigerator is coldest?

Would the temperature readings be different if they were taken near the back wall of the refrigerator, instead of the middle? How would you find out?



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CONCEPTUAL SCHEME

When matter changes from one form to another, the total amount of matter remains unchanged.

(Text pages 98–130)

UNIT CONCEPT

In chemical change, atoms react to produce a change in the molecules.

A Preview of the Concepts

Unit Four

THE TRAVELS OF SOME MOLECULES

Children develop understanding of the interdependence between green plants and other living things that must have oxygen for life, and of the ways that scientists have discovered this relationship.

A VIEW OF THE UNIT

The opening illustration shows two children, green plants, and sunlight. Although something else is there that we know, it is invisible: it is air. The unit develops the important relationships between these things, so that when this illustration is examined again, at the end of the unit, the question "What do you see in this picture?" evokes a deeper and richer answer.

First a simple technique for obtaining a sample of clean air (and other gases) is shown, a technique that is useful throughout the unit. It is known as the *displacement method* of collecting a gas. Water flows out of a bottle as air (or another gas) flows in, and so the invisible gas is kept track of.

Some oxygen gas is produced by placing a pinch of yeast into ordinary drugstore hydrogen peroxide. The hydrogen-peroxide molecules come apart, producing oxygen and water. The oxygen released is collected by the displacement method. A wad of steel wool is put in among these oxygen molecules and compared after a time with a similar wad exposed to air. Children can observe that the wad of steel wool in oxygen rusts more quickly than the steel wool in air. Why does this combining of iron and oxygen to make iron oxide happen faster in oxygen? Children use the molecular theory, once more, to find an explanation. Air is made up mainly of nitrogen molecules (about 80 per cent by volume); oxygen molecules are only about one fifth of the mixture. The steel wool in oxygen clearly can make contact with more oxygen molecules than the steel wool in air with its high nitrogen content.

Iron and oxygen come together to make iron oxide. Somehow, then, molecules are moving around, taking new partners. With the help of models of molecules the children begin to form a concept of the molecular makeup of matter, of the difference between an element and a compound, and of the ways that molecules of elements and compounds may be moved around.

The children observe that as steel wool rusts in air, in a test tube closed by water, the level of the water rises. What can this mean? With the help of water rising in a medicine dropper, they realize that it means that the volume of air inside the tube is shrinking. Somehow, as iron oxide forms, molecules are being taken from the air in the tube. What has happened to these missing molecules?

We know that rusting takes oxygen. We know that air contains oxygen. It seems a good hypothesis (an educated guess), then, that the missing molecules have been removed from the air in the test tube by the rusting. This hypothesis (a reasonable explanation of what is happening) leads to a search for evidence to test the explanation. Some evidence is found and examined. It is in favor of the hypothesis that oxygen molecules are taken from the air to make iron oxide. (Not all hypotheses are so simple or so easy to test!)

A simple test of the air a child breathes in, compared with the air breathed out, shows that the air breathed out is richer in carbon dioxide. A candle produces carbon dioxide too, as the candle burns and takes in oxygen. It happens that the same sort of thing is going on in the body and in the candle. Carbon and oxygen combine to form carbon dioxide, and energy is released—not light energy but energy, nevertheless.

Since the oxygen in air is in such demand, so to speak, and is being used at such a rate, why hasn't it been used up long ago? The discovery by Joseph Priestley that green plants exposed to sunlight give off oxygen gives the answer. Green plants take in carbon dioxide and release oxygen. Animals, on the other hand, take in oxygen and release carbon dioxide. Because there is an oxygen cycle, the oxygen in the air has not been used up. We, since we are not green plants, depend on the green plants for the oxygen we must have to live. So do many other living things. Animals and plants—all living things—are interdependent.

SUPPLEMENTARY AIDS

All films and filmstrips are in color and are rated on the intermediate level of comprehension and concept formation. Addresses of distributors and suppliers are on page F-25.

Films

The Air Around Us (11 min.), E.B.F. Demonstrates that the air around us is real; that it has both weight and volume; that it is essential to all living things; and that it is useful to man in many ways.

Air and What it Does (11 min.), E.B.F. The problem-solving approach develops the basic concepts about air: it takes up space; it expands and contracts; it has weight and force.

Animals Breathe in Many Ways (11 min.), F.A. Shows that all living things must breathe in order to stay alive; they take in oxygen and get rid of carbon dioxide; explains the different ways that animals breath—gills, lungs, etc.

The Air Around Us (12 min., sound), Cenco, 1963. Explains that air is everywhere—in the soil, in water, and in living things; that it takes up space; has weight, exerts pressure; yet is tasteless, odorless, and invisible.

Experimenting with Air (13 min.), I.F.B. Describes the characteristics and properties of air; the power of atmospheric pressure; gives practical examples to stimulate interest in the study of air; how man uses this knowledge.

Filmstrips

Composition of Air (39 frames), Jam Handy, 1961. Shows that air is a mixture of oxygen, nitrogen, and carbon dioxide in constant amounts; that it contains water in varying amounts; explains elements and compounds; explains the importance of oxygen.

Importance of Air in Nature (39 frames), Jam Handy, 1961. Explains the carbon dioxide—oxygen cycle, the nitrogen cycle, and the water cycle; experiment shows what causes rust.

Physical Characteristics of Air (39 frames), Jam Handy, 1961. Experiments prove that air is matter and has volume and weight; air is a mixture of gases and can expand and contract; air is soluble in water.

What Is Air Pressure (39 frames), Jam Handy, 1961. Experiments prove that air exerts pressure; that this pressure can be measured and can be increased or decreased; is caused by pull of gravity.

Atoms and Molecules (43 frames), McGraw-Hill, 1959. Shows by diagrams that everything in the world is made of atoms; atoms of one kind are called elements; atoms of different kinds linked together in molecules are called compounds. Shows parts of atom.

Molecules and You (45 frames), McGraw-Hill, 1961. Explains that everything is made up of molecules; air is made up of several kinds of molecules; what is the oxygen cycle; what causes rust on iron; how movement of molecules differs in the various stages of matter; experiments show changes of water molecules.

Oceans of Air We Live In (45 frames), McGraw-Hill, 1961. Drawings suggest experiments that demonstrate air has weight; that it has pressure; and that this pressure is less at higher altitudes; shows how man uses this increasing knowledge about this invisible ocean of air.

Earth's Blanket of Air (61 frames, sound), S.V.E., 1965. Air is everywhere—in soil, water, and in living things; shows properties of air and its effect on all living things.

Science Reading Table

Starred (*) titles are especially recommended for content and reading level. Names and addresses of the publishers are on page F-24.

Because of a Tree, by Lorus J. and Margery Milne, Atheneum Publishers, 1963. Stresses the interrelationship trees have to the community of which they are a part. Describes eight trees of different communities. (Average)

Exploring Chemistry, by Roy Gallant, Doubleday, 1958. A survey of chemistry from the days of the caveman to the present. Includes the work of famous chemists: Dalton, Priestley, Boyle, Lavoisier, and others. (Advanced, but useful to less capable readers as a reference book for study of selected topics)

Joseph Priestley: Pioneer Chemist, by Rebecca B. Marcus, Franklin Watts, 1961. Describes many of the experiments which Priestley performed, including preparation of oxygen from mercuric oxide. Includes much material on his wide variety of accomplishments and his private life. (Advanced)

Robert Boyle: Founder of Modern Chemistry, by Harry Sootin, Franklin Watts, 1962. Stresses his contributions to science, including his work on the pressure and volume of gases, and the law which bears his name. Includes information about his youth and education. (Advanced)

°*See For Yourself: A First Book of Science Experiments,* by Nancy Larrick, Dutton, 1952. Clear directions and illustrations for each investigation help even reluctant science pupils to have experiences with common materials. Explanation of the results of the investigations are included so that children accumulate some basic science concepts. (Easy)

°*The True Book of Chemistry: What Things Are Made Of,* by Philip Carona, Childrens Press, 1962. Establishes a foundation of basic concepts. The brief simple statements include descriptions of elements and compounds, chemical symbols and formulas, atoms and molecules, and chemical and physical changes. (Easy)

The True Book of Plant Experiments, by Illa Podendorf, Childrens Press, 1960. Simple narration includes description of several investigations. Essentials of plant growth and seed germination and instructions for making a simple terrarium are included. (Easy)

What Is Air, by Albert Piltz, Benefic Press, 1960. Starting with a few easy investigations, the reader is led to consider the less easily observed characteristics of air. Includes information on air as a mixture of gases, air movement, and the use of air in transportation and communication. (Average)

▶ INTRODUCING THE UNIT

You might begin the unit by asking the children to examine the illustration on text page 98 and to read the unit opening on the opposite page. If you ask them what they see in the picture, some children will surely say: a boy and girl, a tree, and air. But isn't there more than one tree? Some grass is visible; and so is the blue sky. How do they know that air must be there? There is one thing more, not mentioned in the printed text, that is visible. It is an important part of the connection between people and air and green plants. Can the class find it? It is light. Not just any sort of light; light from the Sun.

How are people and green plants and air and sunlight connected? This is what the unit is about.

(*Text pages 100–02*)

SUBCONCEPT

Substances have properties that distinguish them from one another.

Section 1: A BOTTLE OF AIR

Children find that clean air can be collected by the method of water displacement and thus gain experience with collection of substances that are invisible.

Processes emphasized

Observation
Investigation (with design of experiment)
Hypothesizing
Theorizing

Equipment and Materials

- . . . empty tumbler
- . . . wide-mouthed jar or small aquarium tank
- . . . colored water

Introducing the Concept

Put an empty tumbler where everyone can see it. If you ask the class what they see, someone may say: "An empty tumbler." Is it really empty? (No, it has air in it, as some child is likely to point out.) This might be your cue to encourage a doubting attitude. How does he know that there is air in the glass? Whatever he answers, remain doubtful. Can he *show* that there is air in the glass, somehow? Can he produce some evidence? Have in readiness a wide-mouthed gallon jar or a small aquarium tank, with colored water in it. A child may suggest that pushing the empty tumbler, mouth down, under water will show that there is air in it. "I happen to have some water . . ." you can say, and bring it forth. Or if the children are groping for evidence without success, you can produce the water as a clue. Now: Can anyone think how the water might be used to show that there is air in the glass? In any case the technique of keeping materials out of sight until they are wanted—or asked for—is particularly useful, especially when introduced by "I happen to have here . . ."

Pushing the upside-down glass under water will trap air in it, and the fact that the water does not rise to the top of the glass may be taken as evidence that something else is present. Why? Because two substances cannot be in the same place at the same time. This does not *prove* that there is air in the glass, to be sure. But it is evidence in that direction. You can assume that an empty tumbler has air in it then. Or can you?

How can you show that two substances cannot occupy the same place at the same time?

Read as far as **Collecting Gases** (text page 100), and do the following investigation.

Air can be collected and cleaned by the displacement method.

Equipment and Materials

See text page 101; also the Teacher's Manual for *Classroom Laboratory 4*.

Developing the Concept

The investigation. The water in the upside-down bottle will not run out so long as the mouth of the bottle is kept under water; but the slightest opening of the mouth above the water will release the water inside, and it may come out with a rush. Keep the mouth of the bottle under water! As air is squeezed out of the bag into the bottle, water leaves the same space at the same time. The solid particles in the air that bubbles up through the water are caught in the water, so the air is washed clean by the water. Some perceptive child may observe that the bottled air must have a lot of water vapor in it. However, the displacement method does show how to keep track of the movement of an invisible gas by observing the movement made by a visible liquid. To take the bottle of clean air out of the water without disturbing the contents unduly, slip the square of plastic under water and snugly over the bottle mouth again.

Collecting gases. You may want to ask your pupils, before they read this section, if they can think of any kind of gas that cannot be collected by displacement of water. (A gas that dissolves in water cannot be collected by this method.) Is there an answer to this question? (Instead of water, use a liquid in which the gas does not dissolve.) What are the bubbles that rise when the cap is taken off a bottle of ginger ale? (They are bubbles of carbon dioxide gas that dissolved in the water under pressure. Taking off the cap releases the pressure, and some dissolved gas reappears.) Household ammonia contains ammonia gas dissolved in water. (Ammonia gas is a powerful irritant, as you know, and should not be examined.)

Air and water cannot occupy the same space at the same time.

Extending the Concept

How much air do you inhale? To get an idea of the quantity of gas that you inhale, fill a narrow-necked jug or bottle with water. Plug the mouth of the bottle with your thumb and invert it in a pan of water. Insert a length of tubing under the water into the jug. Take a deep breath, then exhale through the tubing. How many times must you stop, inhale, and then exhale to fill the container with air? About how much air do you exhale with each breath? If the investigation is timed with a watch or clock, can the number of gallons of air breathed in an hour be calculated?

Equipment and Materials

. . . glass jug

. . . tubing

. . . pan or pot

. . . clock or watch

Reviewing the Concept

(*Text page 102*)

Before You Go On. 1. b 2. a 3. a

Using What You Know. One way of cleaning air would be to pass it through water.

Section 2: A BOTTLE OF OXYGEN

(*Text pages 103–07*)

SUBCONCEPT

A substance may be recognized by its properties.

Children learn more about oxygen, one of the important gases in air; they gain further understanding of the particular nature of matter.

Introducing the Concept

You may want to begin as you did in the preceding section: put an empty tumbler in view, and ask the children what they see. Of course they will point out that the tumbler is not empty but full of air. Set the tumbler upside down on the table. Is it still full of air? Certainly it is, so now you have trapped a sample of air. What is this sample made of? No doubt the children will suggest various substances: oxygen, nitrogen, carbon dioxide, perhaps some of the rare gases, water vapor, dirt and

Processes emphasized

Observation

Investigation (with design of an experiment)

Hypothesizing

Theorizing

Prediction

Equipment and Materials
. . . empty tumbler

other solids. List them on the chalkboard. Which is most important? Oxygen! It supports life. Their logical inference may be: *Then there must be more oxygen in the air than anything else.* Is this true? This question should provoke a discussion as to how much there is of each kind of gas in the air. You may want to note the results on the board. The key question, then, is:

What is air made of?

To resolve doubts and arguments, read to the end of page 103 and do the investigation.

Developing the Concept

Nitrogen is the most plentiful gas in air.

Equipment and Materials
. . . squared paper
. . . colored crayons or pencils
. . . colored blocks or marbles

Breaking down a molecule. It may be helpful to visualize the figures in the table. One way to do this is with squared paper. Lay out 100 squares, say, ten on a side. Let each square represent a molecule. How many squares are needed to represent the amount of nitrogen? Label the group of 78 squares *nitrogen,* and color them one shade. Oxygen will have another color and take up 21 squares. The one square left out of the 100, is nine-tenths argon gas. The remaining tenth of the square represents the amount of carbon dioxide gas, as well as other gases of which there is only a trace. Or the proportions may be visualized with colored blocks or marbles. The important point is that air has much more nitrogen than oxygen.

A molecule of hydrogen peroxide is made up of two atoms of hydrogen and two atoms of oxygen. It breaks down into water and oxygen.

Iron and oxygen combine to form iron oxide, rust.

Equipment and Materials
See text page 104; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. You can obtain fresh hydrogen peroxide at a drugstore. If you have not tried slipping a test tube filled with water into a tumbler of water, as described, a trial or two in private will put your qualms to rest. The yeast and hydrogen peroxide will start producing oxygen as soon as they meet, probably: but there is no cause for alarm. Nothing violent can occur. Just press your thumb over the mixture in the test tube and put it under water. Here again a rehearsal in private begets confidence and you can guide your children the better for it in their efforts. Steel wool for household use is sometimes coated with a rust-resisting substance. Soak the wool in detergent for an hour or so to remove the coating; or ask for uncoated steel wool at a paint or hardware store.

The steel wool in the test tube of oxygen rusts more quickly than the steel wool in the test tube of air. One way of showing that it is the oxygen and not the yeast that causes the rusting is to collect oxygen from the yeast-hydrogen peroxide mixture by displacement of water in another test tube with steel wool in it, connected to the first by tubing. Thus the yeast will be prevented from having contact with the steel wool. Or, through a parent or adult friend, arrange to get a little oxygen in a small balloon, from a welding shop or a hospital. Take care not to allow the balloon near any flame! Transfer the oxygen from the balloon to a test tube containing steel wool by the displacement method shown in the investigation on page 101.

If the water levels in the two test tubes are about the same to begin with, it will be observed that they finish at different levels. The level of the water in the oxygen tube is considerably higher than the level in the air tube. The reason for this is discussed later, in Sections 4 and 5.

Oxygen rusts iron more quickly than air does.

Pure oxygen and air. "When oxygen acts on iron, oxygen molecules and iron molecules come together. They form a new substance called iron oxide." They do not, however, form *molecules* of iron oxide, for iron oxide is not molecular in nature. Just what iron oxide is, is something that chemists are now discussing.

The type of equation in which words are used instead of chemical symbols (iron + oxygen ⟶ iron oxide) is called a "word equation."

To help the children think of why one piece of steel wool in oxygen rusts more quickly than the other piece in air, you may want to suggest drawing a picture to show the proportion of oxygen molecules in oxygen and in air—a diagram, in other words, that anticipates the one on page 106 of the children's text.

More oxygen. A count of the oxygen molecules (red) and the nitrogen molecules (green) in the diagram for "air" on page 106 will indicate the approximate proportion of oxygen to nitrogen in air. Some youngster should ask why argon and carbon dioxide molecules are not shown. To get one argon molecule in the picture, how many nitrogen and oxygen molecules should be shown? (About 78 nitrogen molecules and about 21 oxygen molecules would be required.) Each molecule is shown to be made up of two atoms, which is the number required to display the properties of the substance. One atom of oxygen does not have the properties of the substance oxygen. The molecule of oxygen, made up of two oxygen atoms, is the smallest part of the substance oxygen.

Extending the Concept

Rust prevention. Is paint the only way of keeping oxygen away from iron? Coat some steel wool with water, some with oil, some with nail polish or other household solvent. Your local paint store may have suggestions. Place them all in oxygen, made and collected as in the investigation into oxygen and air (text page 104). Make a chart to display the results.

Equipment and Materials

. . . steel wool
. . . oil
. . . water
. . . nail polish, etc.
. . . oxygen
. . . test tubes

(Text pages 106–07)

Reviewing the Concept

Before You Go On. 1. a 2. b 3. b

Using What You Know. 1. Heavy oil prevents oxygen from reaching the tools, and so prevents rusting. 2. For one thing, we are not adapted to breathing pure oxygen, nor are other living things. For another, rusting and burning would take place much more rapidly than they do now.

(Text pages 107–10)

SUBCONCEPT

The molecules in an element are alike; the molecules in a compound are different.

Processes emphasized

Developing models
Observation
Theorizing
Measurement
Prediction
Investigation

Equipment and Materials

. . . colored cardboard, etc. (as before)
. . . black crayon or lettering pen
. . . double-sided adhesive tape
. . . scissors

Section 3: MOVING MOLECULES AROUND

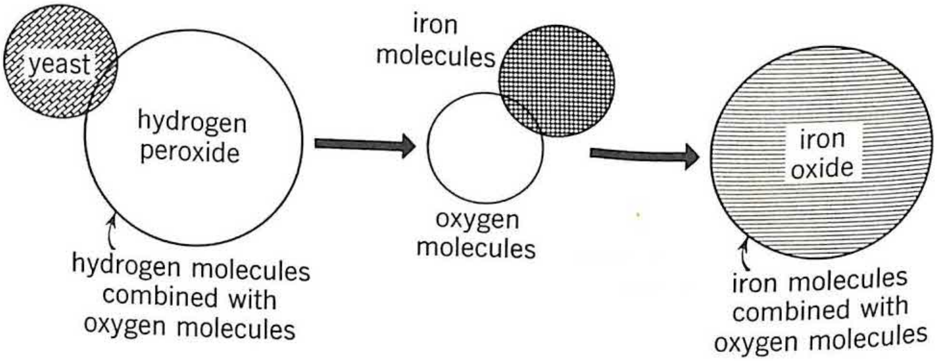
Children gain further experience in chemical reactions; they separate certain molecules from other molecules and join them with still other molecules.

Introducing the Concept

Prepare seven cutouts of colored cardboard and label them, like those shown below. Think big—make the larger ones about 2 feet across so that everyone can see them! Two or three pieces of double-sided adhesive tape on the back of each cutout will hold it to the chalkboard, when pressed. A different color for each cutout enlivens the display, incidentally. Show the cutouts, in mixed-up order, to the children. Can they put the cutouts together in some way to show how iron oxide was made? One cutout overlapping another can indicate bringing the two substances together, and an arrow can show the result. Deciding which cutout goes where should confirm the children's understanding of how oxygen molecules move to form iron oxide. This might be the key question to pose when the cutouts have been arranged in proper order:

Which molecules can move around?

Then begin reading **Moving Molecules Around,** on page 107.


yeast
hydrogen peroxide
hydrogen molecules combined with oxygen molecules
iron molecules
oxygen molecules
iron oxide
iron molecules combined with oxygen molecules

An element is made up of one kind of atom.

Developing the Concept

One substance. To emphasize a point, you might ask the children "What does the picture on text page 107 show?" *The answer "A molecule of oxygen" is wrong.* Nobody has ever seen a molecule of oxygen, let alone taken a photograph of it. The picture shows a *model* of a molecule of oxygen. To emphasize that it is a model, it is held in a hand. There are other kinds of molecule models; this kind suggests that the oxygen molecule is made up of two like atoms that are bound together, which is sufficient for our purposes. Molecules of elements may have one, two, or more atoms. The molecule of helium gas, for example, is made up of just one atom. So is the molecule of the element neon, and the element argon's molecule has just one atom in it. The molecule of hydrogen gas contains two atoms, though; they are alike, so hydrogen is an element. The chlorine gas molecule is made up of two like atoms; chlorine is an element. Nitrogen gas is made up of two like atoms, as modeled on page 106. Color is used for convenience: red stands for oxygen, black for carbon, green for nitrogen, and yellow for hydrogen, in the models.

A molecule of oxygen is the smallest part of oxygen that acts like oxygen. The molecule *can* be divided further—into two atoms of oxygen. But the atom by itself does not act like oxygen.

A compound is made up of more than one element.

More than one kind. What is the difference between the model of oxygen shown on page 107 and the model of carbon dioxide on page 108? Both have two like atoms, of oxygen. But the carbon dioxide molecule has an unlike atom bound in. The carbon dioxide molecule has different atoms bound together; it is a compound. How many atoms of carbon (black) and oxygen (red) are shown in the model of the carbon dioxide molecule? (A molecule of carbon dioxide is made up of one atom of carbon and two atoms of oxygen.) How many atoms of hydrogen and oxygen are there in a molecule of water? (Two atoms of hydrogen, one atom of water. This is what the familiar formula for water, H_2O, stands for, of course.) How many atoms, and what kinds, make up the glucose sugar molecule? (Six atoms of carbon, twelve of hydrogen, six of oxygen.) All this information can be derived by counting atoms in the models of molecules shown on pages 106, 107, 108, and 109.

Molecules can be moved around to form compounds or to obtain elements.

Equipment and Materials

. . . toothpicks
. . . jelly beans or gumdrops
. . . plastic balls
. . . Tinkertoy

Elements and compounds. Children can make their own models of molecules, of course, out of jelly beans and toothpicks for instance, or plastic balls glued together, or Tinkertoy parts. Coloring the parts will help sort them out. You might suggest making a hydrogen-peroxide molecule, which is composed of two hydrogen atoms and two oxygen atoms. Connect the hydrogen atoms side by side. Then connect one oxygen atom to each hydrogen atom at an angle, as the hydrogen atoms are connected to the single oxygen atom in the photograph of the water molecule model on page 108. What happens to this hydrogen-peroxide molecule when it meets yeast? One of the oxygen atoms is released. (It joins with another oxygen atom, released from another hydrogen-peroxide molecule, to make an oxygen molecule.) What's left of the hydrogen-peroxide molecule? (Two hydrogen atoms and one oxygen atom, which form a molecule of water.) Don't try to build a model of iron oxide, however. It is actually a complex combination of oxides.

Extending the Concept

Equipment and Materials

. . . sugar
. . . pan or tin
. . . mirror

What elements are in a sugar molecule? Sugar molecules are made up of carbon, hydrogen, and oxygen atoms. How can you get some evidence of this? Heat a tablespoonful of sugar in an old pan or empty tin. The sugar will melt and eventually turn black. While it is being heated, hold a mirror over the sugar. What forms on the mirror? A film of moisture collects on the mirror. It is water, formed with hydrogen and oxygen from the sugar. What other element is in the sugar? Does the black residue of the heated sugar look like charcoal, or coal, or lampblack? These substances are nearly pure carbon. The black residue is carbon from the sugar. Does it look or taste like sugar? No; the elements are quite different in look and taste from their combination into sugar.

(*Text pages 109–10*)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. b

Using What You Know. Oxygen is an element. Mercury is an element. Since the red substance contained more than one element, it was a compound.

(*Text pages 110–14*)

SUBCONCEPT
Molecules of substances interact.

Processes emphasized

Observation
Analysis
Investigation (with design of experiment)
Hypothesizing
Theorizing
Prediction

Equipment and Materials

. . . bottle
. . . plastic or cardboard square
. . . pan
. . . tubing
. . . water

Section 4: THE RISING WATER

By analyzing the results of a chemical reaction, children infer that a chemical interaction between substances has taken place.

Introducing the Concept

Sometimes just doing something without saying a word of explanation will get all the attention you want from the class and arouse curiosity as well. Half fill a bottle with water where everyone can see you doing it, silently. Close its mouth with a square of plastic or cardboard. Invert the bottle in a pan of water (as in the investigation on page 101). Allow a few moments for inspection of the result. The children will be wondering what you are up to with this old trick that they have seen before. Now is the time to speak. What do they think is in the "empty" space inside the bottle above the water? Air, to be sure. Water vapor too, to be more exact. Now pose this question:

How can the level of the water in the bottle be raised? (Raised without removing the bottle from the water in the pan, that is; and without moving the pan.)

It may occur to the children that they know how to *lower* the level of the water, by inserting a length of tubing under water into the bottle and letting a little air in. Produce a length of tubing that you "happen to have," and let it be demonstrated, just for the record. Some thinkers will quickly announce (if they have not already done so) that reversing the operation ought to do the job: that sucking on the tube should *raise* the water level. If no one specifies that the end of the tubing inside the bottle should be in the air, you may want to arrange that it is under the water there. The sucker will get a mouthful of water, and the point will be made that *air* must be taken from the bottle, for the water level will not change. When air is taken, the water will rise. *Is this the only way of raising the water level?* It is.

Why does the water rise when air is taken out?

Read the section as far as **Something Is Missing** (page 112), and do the investigation.

Developing the Concept

The push of air. You may want to have the class try to explain why water rises in the medicine dropper, before going on. What happened to the water level in the bottle (in "Introducing the Concept") when air was removed? (The water level rose.) What happens to the water level in the dropper? (The water level rises.) Has any air been removed from the dropper, then? (Yes; when the bulb was squeezed, air left the dropper. So water rises in the dropper because some air has been removed.) Why does water rise in a soda straw? (Some of the air in the straw is removed by sucking.) Accept this answer for the moment, but realize that the concept of difference in air pressure needs to be understood before a correction of the answer will be accepted.

Air has pressure.

Equipment and Materials

. . . paper bag

A child may be asked to demonstrate the collapse of a paper bag from which air is taken, with this addition: two classmates may hold the bottom of the bag by its corners, to try to keep it from being pushed in. It will be observed that the pressure of the air outside the bag is real.

Why does water stay up in a bottle upside down in a pan of water? (Air pressure on the water outside keeps up the water inside the bottle, for the pressure outside is greater than the pressure inside. Exposing the mouth of the bottle to the air lets air in. The pressure inside becomes the same as the outside pressure. The water runs out.)

As iron rusts, the air in a closed container is diminished.

Equipment and Materials

See text page 113; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. Get steel wool that does not have a rust-resistant coating or soak the wool in vinegar to remove the coating, before wadding the wool into the end of the test tube. Note the level of the water in the test tube at the start. As the steel wool rusts, the water rises in the test tube. This means that some of the air in the tube is being removed somehow, according to what we have learned from the medicine dropper's behavior. This poses a problem: Where have the missing molecules gone?

As an additional investigation the problem of showing that the steel wool had something to do with the rising of the water can be posed. How do you show that the steel wool caused the water to rise? (Do the investigation again, this time with *two* test tubes in the water. One of the tubes contains steel wool and air; the other contains air only.)

Some molecules of air seem to disappear when iron rusts.

Something is missing. As the iron in the steel wool becomes iron oxide, rust, the water level rises in the test tube. Since the tube is closed by the water, this must mean that the air in the tube has somehow become less than it was. What can have happened to the air? Perhaps this is one place to begin to ask, what is air? Air is a mixture of gases, that is, a mixture of different molecules. What would happen if some of these molecules were in some way taken from the air? The amount of air would be lessened. You can encourage hypotheses and, when practicable, investigations to test them.

Extending the Concept

How long can rusting go on? The investigation into disappearing molecules can be carried further. It will be observed that the water rises to a certain level in the tube, as the iron rusts, and stops. Ask for predictions. What will happen if the water in the test tube is emptied out and the tube put back in the pan of water as before? (As rusting continues, the water level will rise again.) After this has been observed, the natural question is: How often can this process be repeated? (It can go on until the rusting is complete.) Or try the investigation using a dry test tube and dry steel wool. What do you predict will happen when there is no moisture?

Reviewing the Concept

(Text page 114)

Before You Go On. 1. b 2. b

Using What You Know. The water is held up in the tube by the pressure of the air on the water outside the tube.

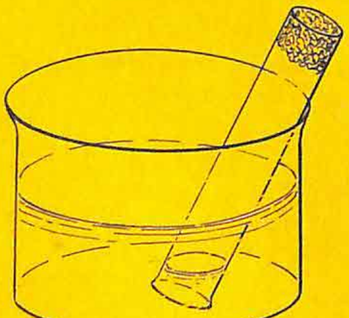
Section 5: FINDING THE MISSING MOLECULES

(Text pages 115–18)

SUBCONCEPT
Molecules of substances interact.

Processes emphasized
Observation
Hypothesizing
Theorizing
Investigation (with design of experiment)
Invention

Equipment and Materials
. . . chalkboard
. . . colored chalk



Children test the hypothesis that rusting takes molecules of oxygen from the air.

Introducing the Concept

To carry forward the problem of what happened to the missing molecules, you might put on the chalkboard a large diagram of the test tube, steel wool, and water, as shown in the figure at the side. Ask for labels for the parts. (Water, steel wool, air.) What does steel wool contain? (Iron.) What does air contain? (Nitrogen, oxygen, argon . . .) Let a child write them on the board as they are given. What happened to the iron in the steel wool? (It rusted.) What happened to the water level in the test tube? (It rose. Have children picture both these events on the diagram.) And what happened to the air in the tube? (It decreased.)

If some children have already made a connection between what happened in the test tube and the formation of iron oxide, let one of them propose it. If not, you may guide them toward the connection. What happens when iron rusts? Have the word equation that is given on page 105 of the text written on another section of the chalkboard:

iron + oxygen ⟶ iron oxide

What does iron take as it becomes iron oxide? (Oxygen.) Draw a circle around "oxygen" in the word equation—and then draw one around "oxygen" in the diagram on the other part of the board. Connect the two circles with a long line.

Does the iron in the test tube take oxygen from the air in the test tube?

Is this a good hypothesis? How could it be investigated? After sufficient discussion, turn to the text and read the complete section.

Developing the Concept

A scientist's guess. Isaac Newton once said, "No great discovery is ever made without a bold guess." What do you think he meant? Sometimes people speak of making "an educated guess." What do they mean? (A guess based on knowledge, perhaps by a specially trained or educated person.) An auto mechanic, for example, can make an "educated guess" about what is wrong with a car. He then proceeds to look for evidence that will confirm his hypothesis or contradict it by examining the car. You may want to use (or use again) the approach to "hypothesis" and "theory" suggested in Unit One, Section 4, "Extending the Concept" (page T-13), of putting some object in a paper bag and letting the children develop hypotheses about what is in the bag, on the basis of available evidence. The willingness and ability to make guesses, on scanty evidence or intuition, can be an asset to a scientist, if he uses a guess as a hypothesis, and searches for evidence with it.

A hypothesis is based on observation and analysis of objects and events; it determines the design of an investigation.

One fifth is missing. To make the point that there is a definite limit to the amount of oxygen that the rusting iron can take from the air in the test tube, you might have a drawing on the chalkboard similar to the lower one on page 106. The red oxygen molecule models can be erased one by one as they go to the steel wool. A green nitrogen molecule should be moved into the empty space so that the overall area shrinks, representing the diminishing amount of air in the tube. Up to how many molecules of oxygen can be taken from this sample of air? How many will be left? What proportion has been removed? (One fifth.) Or nitrogen and oxygen molecules may be represented by green and red marbles, beads, or other objects. If they are put in a glass jar, taking out the red ones will visibly shrink the volume of the remainder, and show too that it cannot shrink beyond a point. (Use 99 marbles—see page 103.)

About one fifth of air is oxygen.

Equipment and Materials

. . . red and green marbles
. . . glass jar

Another check. It may occur to some ingenious child that the process shown on page 117 ought to work the other way 'round, too. That is, if the candle is used first to take oxygen from the air in the cylinder, then fresh steel wool should not rust in such air. True enough, but other things may happen as well. The candle will heat and expand the air in the glass cylinder so that some air will leave. When the candle goes out, the cooling air in the cylinder contracts, and a fresh supply of air (and oxygen) may enter.

A hypothesis must be tested with evidence.

Extending the Concept

Forming hypotheses. More exercise in forming hypotheses can be given in many ways. Put a small piece of Dry Ice in a glass jar. (*Always* use tongs to handle Dry Ice.) Cover the jar with a piece of cardboard. The Dry Ice, which is solid carbon dioxide, will turn to carbon dioxide gas, filling the jar. Set the jar before the class. Remove the cover and thrust a lighted candle into the jar. It will go out at once. Why? What is in the jar? Is there evidence for what is *not* in the jar? You may want to have a similar jar at hand to show how the candle behaves in air.

Equipment and Materials

. . . Dry Ice
. . . glass jar
. . . cardboard
. . . candle

Reviewing the Concept

(Text page 118)

Before You Go On. 1. b 2. a 3. a

Using What You Know. The evidence at hand suggests that it is unlikely that there is life on the Moon like that on Earth (i.e., probably no air or water). But we do not have enough evidence yet, we know, to confirm this hypothesis beyond doubt. A trip to the Moon may provide the evidence.

Section 6: THE USES OF OXYGEN

(Text pages 119–22)

SUBCONCEPT
Molecules of substances interact.

Processes emphasized
Observation
Analysis of observations
Investigation (with design of experiment)
Hypothesizing
Theorizing
Prediction

Equipment and Materials
. . . clock or watch with second hand

Children analyze the similarities between burning of a candle and oxidation in the body.

Introducing the Concept

Just how do we know that our bodies must have air to do their work? The obvious way is, of course, that if our air supply is cut off, we soon become very uncomfortable; and we know that if the supply is cut off for too long, our bodies will cease to function. How is it that we can manage with the air cut off for a little while? (Our lungs store a certain amount of air.) There is an easier way, however, of showing that air has some connection with the working of the body. Let each child count the number of breaths he takes during half a minute, say, by the clock, while sitting quietly. (The counting should be silent, and the result written down by each child.) Now, if the children do some mild work, such as running in place, what do they predict will happen to their breathing? They will probably predict that the breathing rate will increase; but half a minute or so of running in place will prove surprising. Timed again, the breathing rate will not have changed very much. Does anything change? (Yes—the children can observe that they are breathing more deeply.) They are taking in more air. More work means more air needed, or more exactly, more oxygen needed. Why?

What do our bodies do with the oxygen we take in?

Read text page 119, and do the investigation on the next page.

Developing the Concept

Exhaled air contains carbon dioxide.

Equipment and Materials
See text page 120; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. Where does the air that is pumped into the balloon come from? (The pump takes air from the room.) Where does the air that a child blows into the balloon come from? (From the child's lungs.) We assume, then, that the difference in the behavior of the two air samples is due to one sample having been in the lungs. If you like, however, you can point out that there is another difference between the samples. What is the other difference? (One air sample is contained in a green balloon, the other in a red balloon.) How do they know that the *color* of the balloon is not changing the limewater? The answer is, they *don't* know. How can they find out if the color of the balloon affects the limewater? (By switching balloons. Use the green balloon this time for pumped air, the red for breathed air.) The problem may be posed as an additional investigation, if desired. Should it be assumed that every child's breath turns limewater milky, now that one child's breath has done so? (No; better test a few more samples, at least.) Emphasize that great care must be taken when letting air out of the balloon into the limewater. (Note how the neck of the balloon is held in the photographs.)

What you do with oxygen. As the investigation suggests, the air we exhale contains carbon dioxide. We manufacture carbon dioxide in our bodies. Why is this so? Strangely enough, a candle can suggest what is going on inside the body. You might place a lighted candle, safely mounted in a holder, where everyone can see it while reading. What is the carbon dioxide like that the candle gives off as it burns? It is a colorless, tasteless, odorless gas. As carbon molecules and oxygen molecules join together to make carbon dioxide molecules, they give off energy. This energy is given off in the form of light and heat from a candle. In the body, heat energy is produced. (Some animals do give off light, however; fireflies and glowworms, for example.)

Oxygen gives energy when it combines chemically with carbon.

Equipment and Materials

. . . candle
. . . candle holder

Extending the Concept

Fighting fire. Burning requires oxygen; what is one way to fight fire, then? (Cut off the oxygen supply.) This may be a good time to show a fire blanket and discuss how it works; to demonstrate a foam extinguisher; to discuss why a pan of burning grease should be covered to put out the fire, and why water should *not* be used. Your local fire department will probably be glad to help here.

(*Text page 122*)

Reviewing the Concept

Before You Go On. 1. b 2. b 3. a

Using What You Know. The heat energy from a candle warms things near the candle, including the air, which expands and rises. The light energy is reflected or absorbed, or perhaps travels out into space. We use the heat energy produced in our bodies to work and play.

Section 7: THE RETURN OF OXYGEN

(*Text pages 123–27*)

SUBCONCEPT
The substances in air are affected by the action of green plants. (Green plants give off oxygen in light, and take in carbon dioxide.)

Children analyze relationships in the actions of green plants in light. They study the relationship between the oxygen and carbon dioxide as it is affected by green plants.

Introducing the Concept

We use up oxygen; other living things use up oxygen; nonliving things use up oxygen (a burning candle, rusting, any oxide). You might ask the children to bring to class something that uses up or has used up oxygen. Be prepared for anything, especially pets, but do note that nonliving things that have used up oxygen are included in the invitation. The point is that oxygen is being taken from the air; the question is: *Why hasn't the oxygen in the air been used up long ago?* The air holds only a limited amount of oxygen, after all. (If some well-

Processes emphasized

Observation and analysis
Investigation (with design of experiment)
Hypothesizing
Theorizing
Prediction

informed youngster says that green plants are putting oxygen into the air, you might treat his statement as a hypothesis. How can this hypothesis be tested? How can we get some evidence for it or against it?) When the discussion has gone far enough, you can suggest that the text may throw some light on the question:

How do we get a fresh supply of oxygen?

Read as far as **The Gas a Green Plant Makes** (page 124), discuss, and then do the investigation.

Developing the Concept

Green plants give off a gas.

A green plant in a jar. "Nothing could get in or out of the jars," the text says, and, strictly speaking, this is true. But watch to see if it occurs to any child that the glass allows light energy to go in. So the plants in the jars were not completely sealed off from the outside world.

Equipment and Materials

- . . . test tubes
- . . . branches of ivy
- . . . pan
- . . . water

(See also text page 125, and the Teacher's Manual for *Classroom Laboratory 4.*)

The investigation. If you have an aquarium at hand, let the children make observations with it, of course. As the photographs show, the elodea plants produced bubbles in the light and produced no bubbles when there was no light. Do other green plants behave like elodea plants? Fill a test tube with water. Using your thumb as a stopper, invert the tube in a pan of water. There should be no air in the test tube, only water. Push a branch of ivy, cut end up, into the very tip of the tube. Set in sunlight. What happens? (Air appears at the tip of the tube, in a few hours.) But pose these questions now: Should another tube and branch of ivy be placed in the dark? Should a tube of water, without ivy, be placed in the light? in the dark?

Oxygen is given off by green plants.

Equipment and Materials

- . . . elodea plants
- . . . beaker or jar
- . . . funnel
- . . . test tube

The gas a green plant makes. If you have an aquarium at hand, you may want some children to set up the arrangement shown on page 124, for collecting the gas given off by a plant under water. The test tube should be full of water to begin with, of course. Bubbles rising from the plant will gradually displace the water. Or let children cut the tips off five or ten branches of fresh elodea (from an aquarium supply store), and arrange the tips under a funnel, so that slipping on the test tube will be easier. Otherwise the funnel must be slipped under the inverted test tube below water. The first sample of gas collected will probably have a considerable amount of air in it; discard it if you want to perform the glowing splint test for oxygen and use the second sample collected. Why is all this done under water? To make visible the fact that the plants give off a gas. Oxygen is being given off by green plants all around us, but we cannot see the colorless gas; nor can we smell it, for it is odorless. However, it is most important to show in these investigations what part light plays. Will artificial light cause the plants to make oxygen? (It will.) The observation that these green plants make oxygen is not enough; the green plants make oxygen *in light.* Light energy is required. The Sun, source of this light energy, is important.

Oxygen and carbon dioxide form a cycle.

Another cycle. The water cycle was introduced in Section 8 of Unit Two, pages 93–97 of the text; you may want the children to look at it again and diagram it on the chalkboard. The illustration on page 126 shows two children and a tree. What other things could be put in the picture in place of the boy and girl? What other plants might be put in place of the tree? Sometimes the oxygen cycle is called the oxygen-carbon dioxide cycle. Why?

Extending the Concept

What is a balanced aquarium? Why does an aquarium have to have both plants and fish? (Plants supply oxygen for fish, fish supply carbon dioxide for plants.) How do fish show that an aquarium should have more plants? (If the fish come to the surface for air often, the water may lack oxygen.) Would you add more plants to the water or remove some? (Add plants to increase the supply of oxygen.) How can water plants be made to produce more oxygen? (Give the plants more light. If the aquarium lacks sunlight, an aquarium supply merchant can show how artificial light may be used.)

Another test for carbon dioxide. Obtain from a drugstore a small quantity of the harmless indicators called bromthymol blue and bromthymol yellow. Put some of the bromthymol blue into a glass and blow into the liquid through a straw. As carbon dioxide in your breath bubbles through, the bromthymol blue turns yellow. What color change would you expect if carbon dioxide were *removed* from the bromthymol yellow? The bromthymol yellow would turn blue.

Fill four test tubes with bromthymol yellow. Put sprigs of elodea plants in two of the tubes. Wrap a tube with a sprig of elodea and a tube without a plant in carbon paper, to prevent light from reaching them. Set all four tubes in sunlight or under a bright electric light. Inspect them in about an hour. In which tubes has the solution turned blue? (In the tube with the sprig of elodea exposed to light, only.) Why did the solution turn blue? (Carbon dioxide was taken from the solution by the elodea plant in light.)

Equipment and Materials

. . . bromthymol blue
. . . bromthymol yellow
. . . elodea plants
. . . test tubes
. . . carbon paper
. . . light

Reviewing the Concept

(Text pages 125–26)

Before You Go On. 1. a 2. a 3. b 4. b 5. a

Using What You Know. The grass produces oxygen that the cow uses; the cow produces carbon dioxide that the grass uses.

(Text pages 127–30)

CONCEPTUAL SCHEME
When matter changes from one form to another, the total amount of matter remains unchanged.

UNIT CONCEPT
In chemical change, atoms react to produce a change in the molecules.

Section 8: THE MAIN CONCEPT: AN IMPORTANT CYCLE

Children come to understand that, as they and other living things are part of a water cycle, they are part of an oxygen-carbon dioxide cycle in which they capture matter from their environment and return it.

CONCEPT SUMMARY

What do you see in this picture?

Why not return for a few minutes to the starting point of this unit, the unit opening illustration and text on pages 98 and 99? Now the question posed in the text may be asked again: What do you see in this picture? Now the answer may be rich indeed, especially if the word "see" may include what is perceived with the mind as well as with the eye. The children may see, then, not just a girl and a boy, a tree and other green plants, light, and air—but molecules of oxygen and carbon dioxide moving between the living things in the picture in an endless cycle, moving with energy from light. Perhaps the children see now that all the things in the picture are connected, in a way that is as necessary for life as the invisible air. Perhaps they see now that the boy and girl are a part of what is in the picture, not apart from it.

Why do we need oxygen?

Why is this so? Turn to **The Main Concept: An Important Cycle,** text page 127. Among all the things we need, we must have oxygen. We use it to live. We combine oxygen with the food we eat and get energy for living.

Where do we get oxygen?

We take oxygen from the air. But so do other living things. So do nonliving things. The oxygen in the air ought to have been used up long ago; yet there is still oxygen in the air.

Why hasn't the oxygen been used up?

The scientists look for an answer to this riddle. They discover, piece by piece, and through many investigations and experiments over many years, why the oxygen did not disappear long ago. As a green plant receives sunlight, the plant gives off oxygen. The green plants are putting oxygen into the air. We depend on green plants for oxygen. So do other living things. How do we depend on green plants for oxygen? The answer is summed up in the oxygen cycle. Living things turn out molecules of carbon dioxide, as the illustration on page 128 suggests. Green plants take them in, given light energy to do it with. Green plants turn out molecules of oxygen. We take them in. So do other living things.

How do we use oxygen?

In our bodies the oxygen molecules are combined with carbon molecules which we take in as part of our food. By combining oxygen and carbon molecules we get energy, the energy we must have to live. Presently we return carbon dioxide to the air. The carbon dioxide is used by a green plant. So the cycle continues. We, and other living things, are a part of the cycle.

Why do we need green plants?

Look again at the illustration on page 128. What other living things can you put in place of the boy, and keep the cycle running? *Any animal.* What other living thing can you put in place of the green plant? None.

FIXING THE MAIN CONCEPTS

(*Text pages 129–30*)

Testing Yourself. Balloon A in the illustration on page 129 is being filled with fresh air by a pump. Balloon B is being filled with air from the lungs.
1. b **2.** a **3.** a **4.** b **5.** a **6.** b **7.** a **8.** a **9.** a **10.** a

A NEW VIEW OF MATTER

(*Text pages 131–33*)

CONCEPT RELATIONSHIPS

Matter is made up of tiny particles having different arrangements; matter changes its state; matter changes its form. When matter changes from one form to another, the total amount of matter remains unchanged.

In this second New View, the concept of the molecular theory is examined as a means for explaining the behavior of matter and for enabling us to predict what will occur when matter undergoes a chemical change of form or a physical change of state. It also helps explain how in these changes the total amount of matter remains unchanged.

TEACHING SUGGESTIONS

Matter is of many kinds.

Kinds of matter. How many different kinds of matter can the children find around them? You need not be very particular about identifying the matter exactly. The state of the matter, however, should be included: Is it solid, liquid, or gas? What are the most different kinds of matter in view? Yet all matter is made up of tiny particles: atoms and molecules.

Matter is not all molecular.

Molecular theory. We have to be cautious here, though. Chemists used to say that all matter is made up of molecules. They no longer believe this to be true, for they have found that some substances are collections of atoms held together by electric charges in a way that doesn't answer the description of a molecule. Common table salt, for instance, is made up of sodium atoms and chlorine atoms held together, but not as molecules. Iron oxide is made up of iron atoms and oxygen atoms held together, but there is no molecule of iron oxide. What are such collections of atoms to be called? If you will pardon the pun, the chemists are looking into the matter. At any rate, the statement that *all* matter is made of molecules should not be made. There are exceptions.

What is the point of taking a molecular view of matter? What do we gain by this molecular theory, that things are composed of molecules and atoms? You may want to pose these questions. The answer is that the theory helps us to understand the behavior of matter and to predict its behavior. Some examples of the behavior of matter that we can better understand with the help of the molecular theory are given in the following section.

The usefulness of the molecular theory.

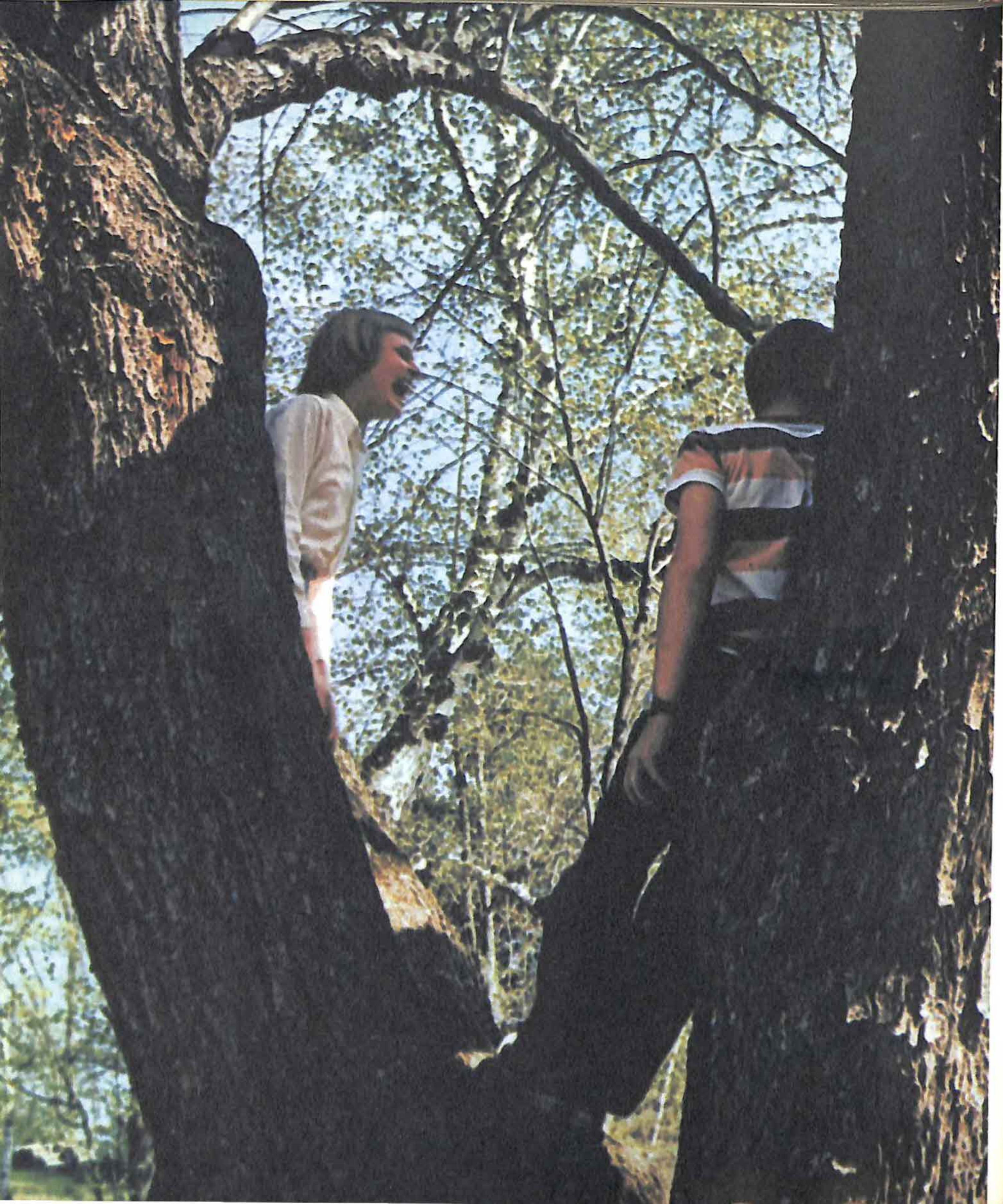
Particles and changes. Water evaporates: it disappears. How is this disappearance of a substance to be explained? Some of your children might like to try to answer this question without making use of the molecular theory. How can the change of state of water from solid to liquid, from ice to water, be explained? The molecular theory makes it easy to imagine the molecules of water vibrating in a fixed position in the solid state, free to move over and around each other in the liquid state. When the liquid water becomes a gas, water vapor, the molecules move much farther apart, and have much more freedom of movement.

What about the heat energy that is needed to change ice to water and water to water vapor? Using the molecular theory, the role of heat energy can be explained. There is more movement of the molecules of water as it goes from solid to liquid and from liquid to gas. The heat energy supplied is changed into another form of energy, into the energy of motion of the molecules.

When a substance like water changes its state, as heat energy is added or taken away, the substance undergoes a physical change. What of chemical changes? The molecular theory is useful in accounting for chemical changes as well. Oxygen enters the body when you breathe in; when you breathe out, some of that oxygen leaves the body, but as part of a different substance, carbon dioxide. A chemical change has taken place. How do we explain this change? By thinking of oxygen and carbon dioxide as molecules: molecules made up of different atoms, which can be moved around to form different substances.

You and your pupils have been brought up with the molecular theory, so to speak, and probably find it difficult to imagine any other way of thinking about matter. There were men in ancient Greece who speculated that matter was made up of tiny invisible particles—atoms. But it was a long time before men found out how to get convincing evidence for the hypothesis. Compared with the length of man's history, the theory of molecules and atoms is really a new view of matter.

TEACHER'S NOTES



UNIT FOUR

THE TRAVELS OF SOME MOLECULES

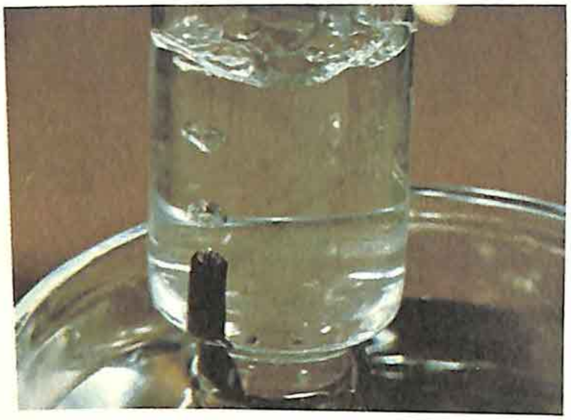
What do you see in this picture?

You see a boy, a girl, and a green plant, of course. There is something else in this picture, however. It surrounds the boy and girl and the green plant. It cannot be seen, yet you know it must be there. It is invisible, but it can be felt. It is air.

There is a connection among the three things in the picture, among people and air and green plants.

People breathe air, to be sure. There is a connection. What do green plants have to do with people and air? That is what this unit is about.

We begin with a bottle of air.



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1. A Bottle of Air

If you were asked to collect a bottle of air, how would you do it? Perhaps you think that getting a bottle of air is easy. It is, isn't it?

There is air all around us. What we call an "empty" bottle is already filled with air. To get a bottle of air is not hard.

What we want, however, is not just a bottle of air. We want a bottle of *clean* air. We need a bottle of air that has none of the dust and dirt that air usually carries. Dust and dirt are solids, tiny solid specks. How can we get a bottle of clean air free from the dust and dirt and other solids that are usually there?

There is a simple way of getting a bottle of air that is free from solids. Try the investigation on the opposite page to see how it's done.

Collecting Gases

Air is a substance. Anything that is a substance takes up space. Air takes up space.

Water is a substance, too, and takes up space. What happens when air enters the bottle of water in the investigation? Two substances cannot be in the same space at the same time. As air is pushed into the bottle, water is pushed out. The air takes the place of the water, or **displaces** the water. As air displaces water in the bottle, you can see it happening, even though air is invisible. See the picture marked with a square. ■ This way of collecting air is called the **displacement method.**

As air is collecting in the bottle, it passes through the water. As the bubbles rise through the water, the air in the bubbles is washed clean. Any solids in the air are washed out by the water. So the bubbles that rise to the surface of the water inside the bottle hold clean air. The result is a bottle of air without solids in it.

The displacement method is one way to collect a gas. There is a problem in collecting a gas in this way, though.

Imagine you are watching ammonia gas being collected by the displacement method.

AN INVESTIGATION into a Way of Collecting Air

Needed: a plastic bag, a plastic or rubber tube, a square of hard plastic, a small bottle, a pan, string, and water

Put about 2 inches of water in the pan. Fill the bottle until it overflows.

Push the flat piece of plastic over the mouth of the bottle, so that it closes the bottle without any air getting in. Now there is only water in the bottle.

Hold the plastic tight over the mouth of the bottle. Turn the bottle upside down. Place the mouth of the bottle under the water in the pan. ■ Pull out the plastic, keeping the mouth of the bottle under the water. The water in the bottle will not run out.

Now open the plastic bag wide, so that there is plenty of air in it. Tie the bag of air to one end of the tube. ●

Put the other end of the tube under the water into the mouth of the bottle. Do not let the mouth of the bottle come out of the water. ▲

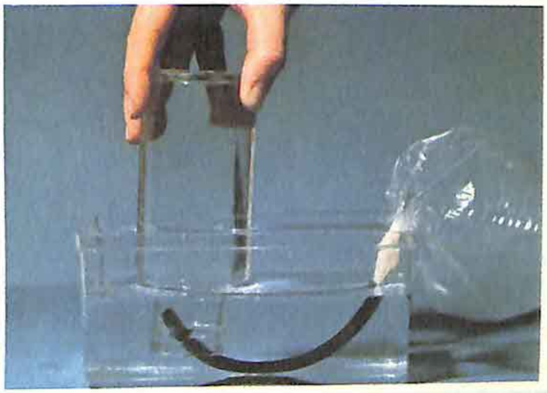
Press the bag of air. Air is squeezed out of the bag. Where does it go? How do you know? Here is what happened in one trial. ◆

What happens to the water in the bottle as air is squeezed out of the bag? Why?

How does the air that is squeezed out of the bag get cleaned?

■

●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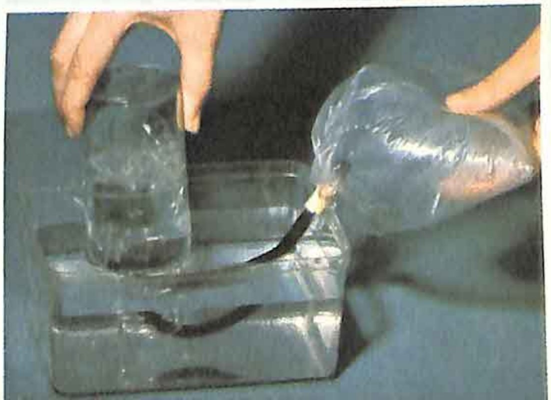

◆

Although the ammonia gas has been going into the bottle of water for some time, no gas has collected. Something strange happens to the bubbles. They get smaller and disappear as they rise. The problem is easily answered if you know this fact. Ammonia gas dissolves easily in water.

Air does not dissolve easily in water, as you can see. But a tiny bit of the air passing through the water does dissolve in the water. Water can hold some dissolved air. You have often seen evidence of this, although you may not have known it. What do you suppose the bubbles are that rise when you heat water?

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. An "empty" bottle open to the air is
   a. empty b. not empty
2. When air is bubbled into the bottle of water, the air
   a. displaces the water b. dissolves the water
3. A gas that cannot be collected by displacing water is
   a. ammonia b. air

USING WHAT YOU KNOW The air coming into a hospital should be clean. What would be one way to clean the air?

ON YOUR OWN Invent a way to show that air has weight.

2. A Bottle of Oxygen

Now we have a way of collecting gases. Let us collect some oxygen gas for an investigation.

Where can we get oxygen? There is plenty of oxygen in the air around us, of course. Air not only has oxygen in it but other gases as well. Air is a mixture of gases.

All of the gases in air are well mixed together. Suppose that you could count out ten thousand molecules of air. The chances are that you would find these molecules among those ten thousand:

Substance	Number of Molecules
Nitrogen gas	7,800
Oxygen gas	2,100
Argon gas	90
Carbon dioxide	4
Other gases	6
Total	10,000

The air around you has a good deal of oxygen in it, as you can see. Separating molecules of oxygen from other molecules in the air is difficult, however. Special and expensive equipment is needed to do that job. Fortunately, there is another way which we can use for getting oxygen.

We can take a molecule that has oxygen in it as one of its parts. We can then break this molecule apart and take the oxygen.

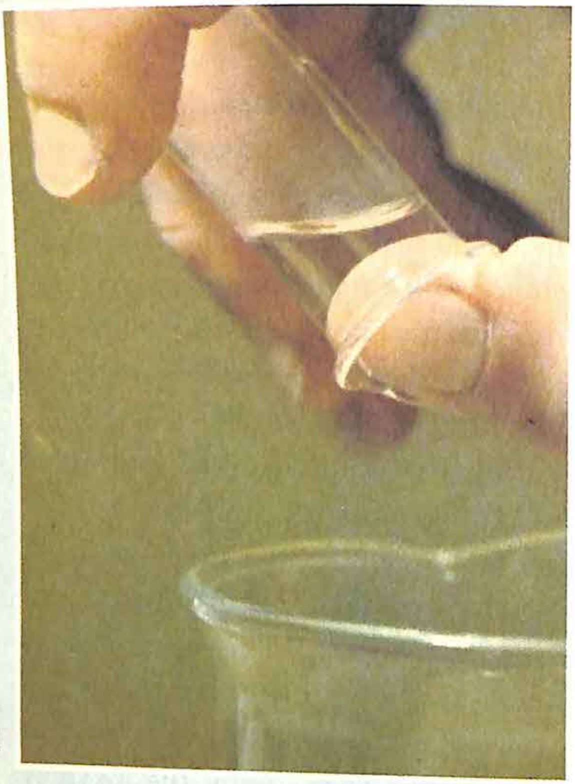
Breaking Apart a Molecule

Many different kinds of molecules have oxygen as a part. Which kind of molecule shall we use? There is a substance called *hydrogen peroxide* (HY·droh·jen per·OK·syd). Hydrogen peroxide has oxygen in it, for it is made up of hydrogen and oxygen.

How can we take apart molecules of hydrogen peroxide and get the oxygen? We can do this with yeast. ■ When hydrogen peroxide touches yeast, the hydrogen peroxide comes apart and gives off oxygen. See for yourself in the investigation on the next page. Then, with the oxygen collected, investigate a difference between oxygen and air.

■

AN INVESTIGATION into Oxygen and Air



Needed: hydrogen peroxide, yeast powder, steel wool, two test tubes, two tumblers

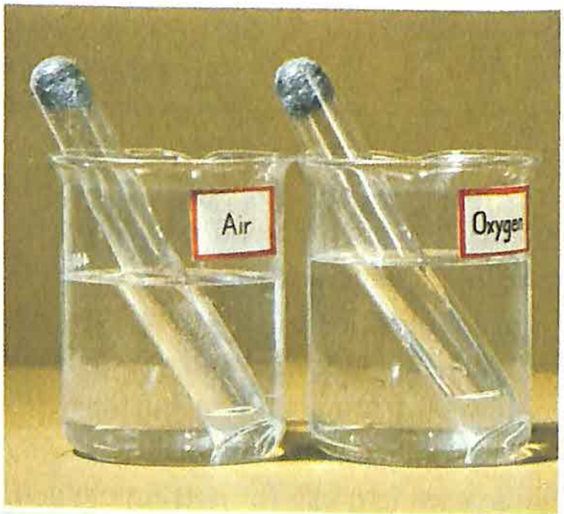
With a pencil, push a wad of steel wool down to the bottom of each test tube. Put just a pinch of yeast powder into one of the test tubes.

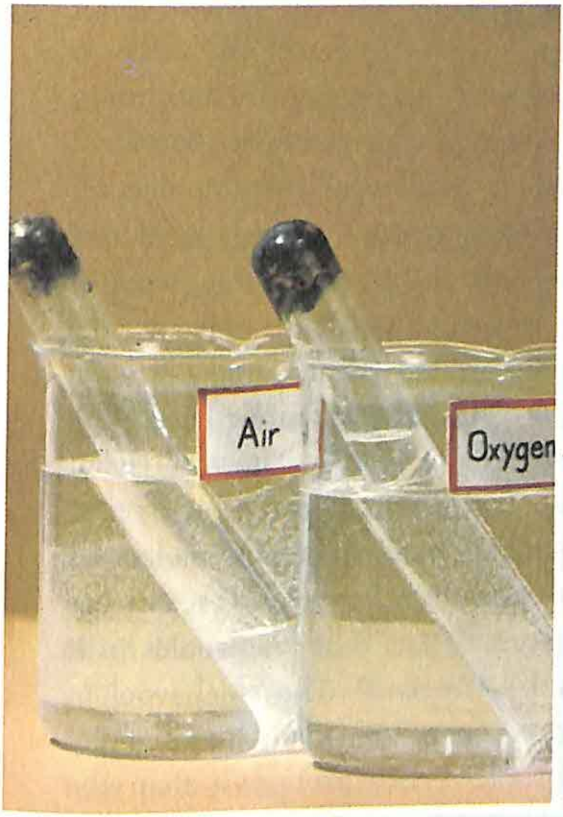
Fill both tumblers with water. Fill the test tube with no yeast in it with water to the very brim. Put your thumb over the mouth of the tube and close it tight. Turn the test tube upside down. Put its mouth under the water in one of the tumblers, keeping your thumb in place. ■ When the mouth of the tube is completely under water, take your thumb off. The water in the test tube will stay up in the tube.

Now fill the test tube with yeast in it to the brim with hydrogen peroxide. Quickly put your thumb over the end of the tube, closing it tight. Quickly turn the tube upside down and put the mouth under water in the second tumbler. Remove your thumb.

Watch the bubbles of gas collect in the top of the tube. The gas is oxygen. As the gas collects, the water in the tube is displaced.

Let out some of the water in the test tube with no yeast in it, so that the steel wool is in air rather than in





▲

water. Now you have a piece of wet steel wool in air, in one tube. A piece of wet steel wool in oxygen is in the other tube.●

Observe the steel wool from time to time during the next few days. What happens to the steel wool in oxygen? In air?

Here is what happened in one trial.▲

Additional Investigation: Perhaps it is the yeast which is responsible for what has happened. Perhaps it is not the oxygen. How would you find out whether it is the oxygen or the yeast which causes the rusting?

Pure Oxygen and Air

Why does one piece of steel wool rust more quickly than the other, in the investigation?

To answer this question we must ask another question. What is happening when steel wool rusts?

Steel is mostly iron. It is the iron that rusts. What happens is that oxygen acts on the iron. When oxygen acts on iron, oxygen molecules and iron molecules come together. They form a new substance called *iron oxide*. We say that the oxygen **combines** with the iron to form iron oxide. Another name for iron oxide is rust.

Molecules of iron combine with molecules of oxygen. They form a new substance that is not like either iron or oxygen. A chemist might write

$$\textbf{iron} + \textbf{oxygen} \longrightarrow \textbf{iron oxide}$$

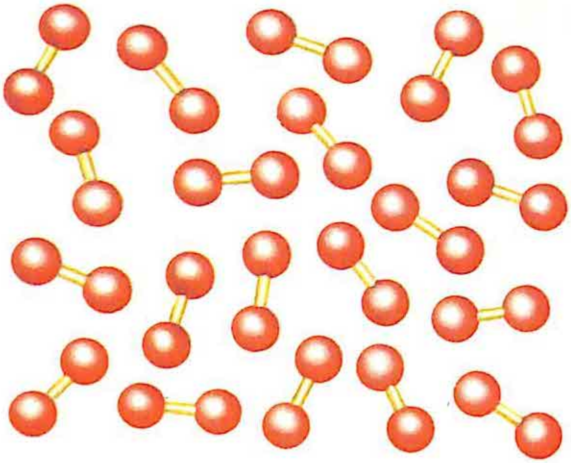
The arrow stands for "becomes." The plus sign stands for "combined with."

Now let us go back to our first question. Why does one piece of steel wool rust more quickly than the other, in the investigation?

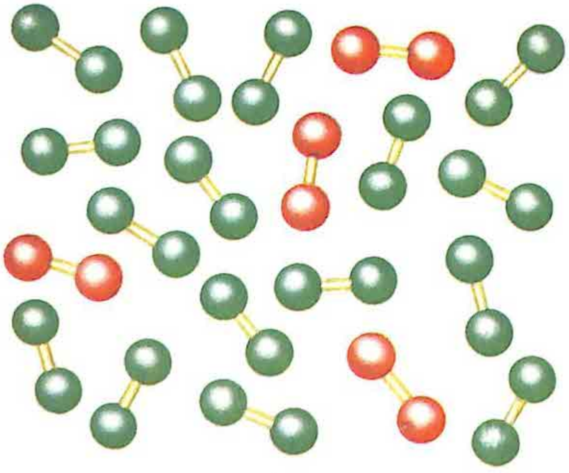
Try thinking out your own answer to this question, before going on.

More Oxygen

In the investigation, one piece of steel wool was in air. The other piece



oxygen ■



air ●

of steel wool was in oxygen. Both pieces rusted. However, the piece of steel wool in oxygen rusted more quickly than the piece in air. Why?

When steel wool rusts, molecules of oxygen combine with molecules of iron. Both the pieces of steel wool in the investigation had molecules of oxygen around them. The steel wool in oxygen was surrounded only by oxygen molecules. ■ The steel wool in air had some molecules of oxygen around it, for air contains molecules of oxygen. Air, however, is a mixture of gases. It has other molecules in it besides oxygen. ● The steel wool in pure oxygen had many more molecules of oxygen around it than the steel wool in air. The iron molecules in the oxygen had many more chances to combine with oxygen molecules than the iron molecules in air.

BEFORE YOU GO ON

Study these statements and choose the correct responses. This will help fix in your mind the main concept.

1. Air is mostly
   a. nitrogen gas   b. oxygen gas
2. Hydrogen peroxide is made of hydrogen and
   a. nitrogen   b. oxygen
3. When iron rusts, it combines with
   a. nitrogen   b. oxygen

USING WHAT YOU KNOW

1. Tools are sometimes stored in heavy oil. Why?
2. Would it be better if the air were made up of oxygen only? Why?

ON YOUR OWN

Where in your house do you find iron oxide?

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3. Moving Molecules Around

We have moved some oxygen molecules around, haven't we? First, they were in hydrogen peroxide. We let them loose by using yeast. Then we tied up those oxygen molecules in rust. We combined oxygen molecules and iron molecules to make a new substance, iron oxide.

When you stop to think of it, being able to let loose or to join up molecules is a remarkable thing.

Let us look more closely at how this remarkable thing happens.

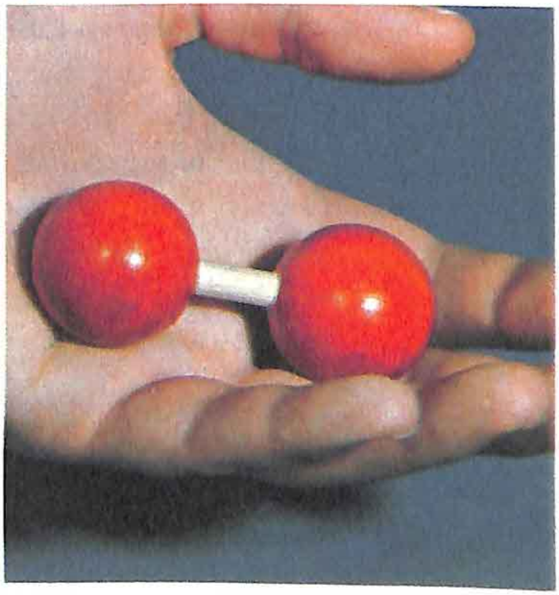
One Substance

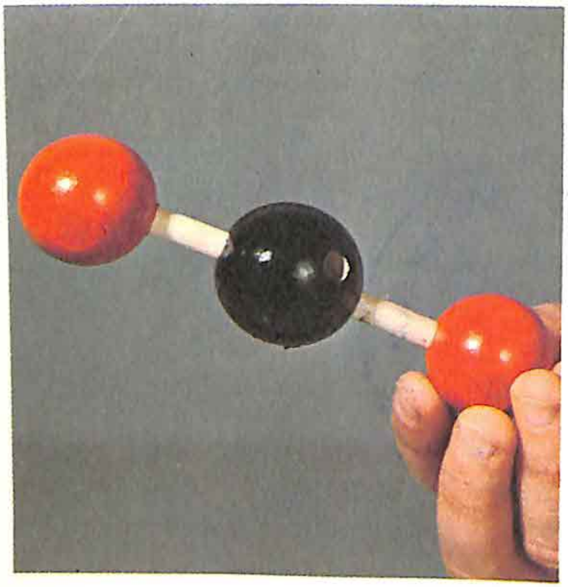
Suppose that you could divide oxygen into smaller and smaller parts. Could you go on dividing forever? No. The smallest part which would *still be oxygen* would be a **molecule**—a molecule of oxygen.

It would be made up of two **atoms,** atoms of oxygen. ▲ If you divided that molecule of oxygen further, you would no longer have oxygen. One atom of oxygen does not act like oxygen. A molecule with two atoms of oxygen does act like oxygen.

A molecule of oxygen is made up of two atoms of oxygen joined together. A molecule of oxygen is made up of just one kind of atom, atoms of oxygen. A substance that is made up

▲





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of just one kind of atom is called an **element**. Oxygen is an element because every molecule has only atoms of oxygen in it. Copper is an element. A molecule has only atoms of copper in it. Molecules of copper cannot be divided into anything smaller and still be copper. Iron is an element, for it has only one kind of atom in it. Nitrogen is an element. The nitrogen molecule is made up only of nitrogen atoms. So nitrogen is an element.

Carbon dioxide, however, is *not* an element. Let us see why.

More Than One Kind

Suppose you could divide carbon dioxide gas into smaller and smaller parts. The smallest part of carbon dioxide would be a molecule. A molecule of carbon dioxide, though, is made up of *two* kinds of atoms, atoms of carbon and atoms of oxygen. ■

A molecule of carbon dioxide is made up of two different elements, then, carbon and oxygen. A substance made up of atoms of two or more different elements is called a **compound.** Carbon dioxide is a compound.

You know many compounds. Water is a compound of the elements hydrogen and oxygen. ●

Sugar is a compound with three elements combined in it. Sugar has the elements carbon, hydrogen, and oxygen combined in it. ▲

A compound may have more than two different elements combined in it.

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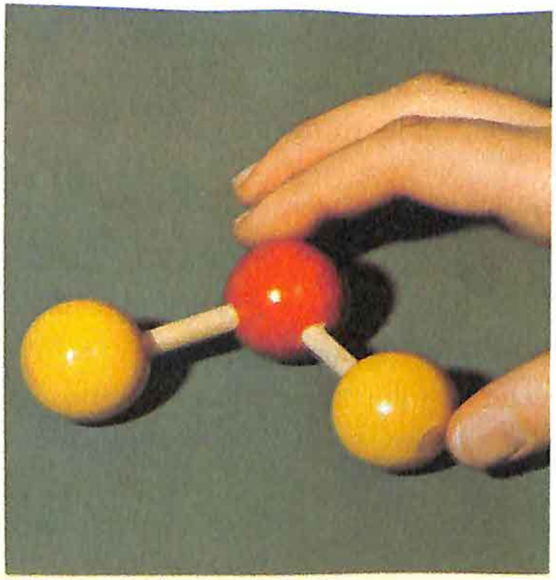
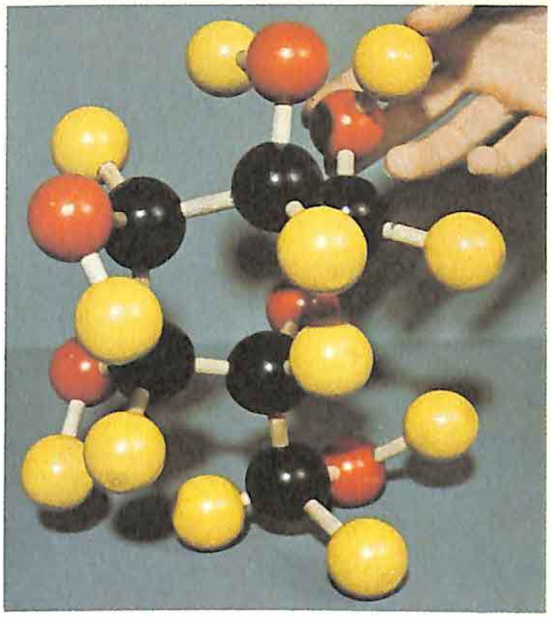


Elements and Compounds

An element is made up of only one kind of atom. Elements may be joined together, or combined, to make a compound. A compound is made up of more than one element. A compound may be broken apart into elements. This is what we were doing when we moved those molecules of oxygen around. We began with a bottle of hydrogen peroxide. Hydrogen peroxide is a compound that has two elements, hydrogen and oxygen, combined in it. By putting yeast in hydrogen peroxide we let the oxygen loose. The oxygen came loose as a gas, which we collected.

We put the oxygen together with iron. The molecules of oxygen and the molecules of iron combined. They formed another compound, iron oxide.



Thus we took an element from a compound, combined it with another element, and made a new compound. We moved oxygen molecules around and gave them new neighbors. We let loose some molecules and joined up some molecules.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. All substances are made up of
   a. other substances b. molecules

2. When a molecule is made up of only one kind of atom, it is
   a. an element b. a compound

3. When a molecule is made up of two or more elements, it is

a. an element b. a compound

USING WHAT YOU KNOW A red substance is heated. It gives off oxygen and mercury. The substance must be either an element or a compound. Which do you think it is? Why?

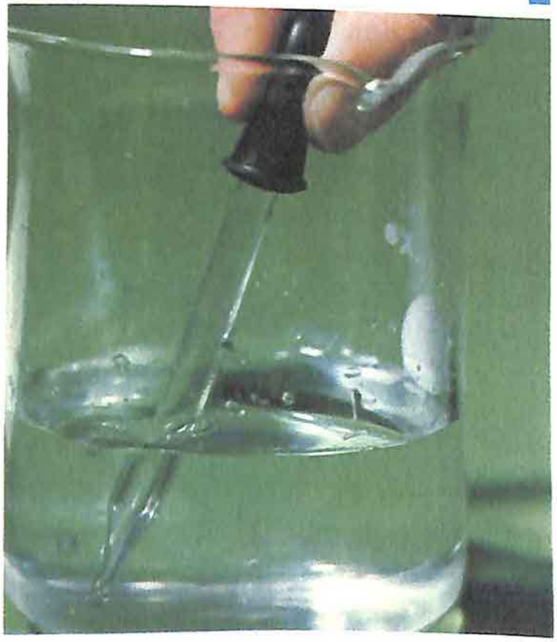
ON YOUR OWN What elements and compounds can you find in your home?

4. The Rising Water

Let us move molecules of oxygen around in still another way.

Take a glass of water and an empty medicine dropper. Put the tip of the dropper under water and squeeze the bulb.■ What happens? Bubbles of air come from the dropper. The "empty" medicine dropper was full of air, of course. When the bulb is squeezed, air is pushed out. There is nothing mysterious about that.

■



What happens next really is a little mysterious, though. Keep the tip of the dropper under water. Gently let the bulb swell up again. What happens in the dropper?●

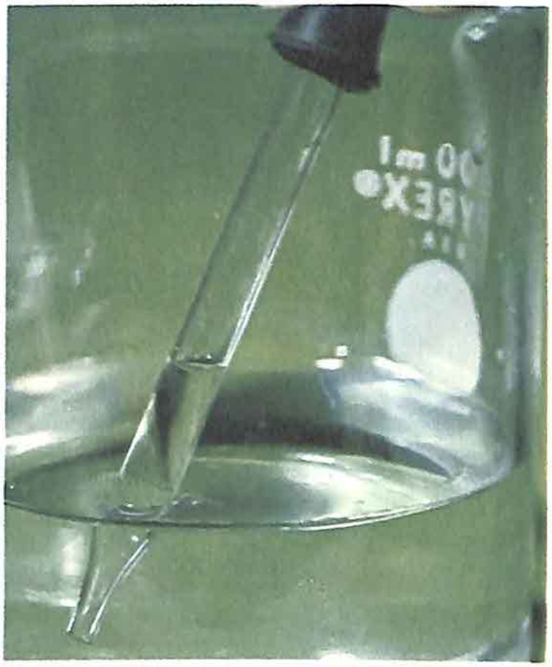
As the bulb swells up, water rises in the dropper. How can you explain this?

The Push of Air

Water rises in the medicine dropper when the rubber bulb is released. "The water is sucked up," someone may say. But water is not really sucked up. It is *pushed* up. Something is pushing the water up into the dropper. What is this something?

You probably know that the air around you is pressing on everything it touches, all the time. We say that the air has **pressure.** A good way to show that this is so is with a paper bag. Put your hand in the bag and push its sides out as far as they will go. Now you have a bag full of air. ▲

Now take some air out of the bag by sucking. ◆ What happens to the bag? It crumples up, as if you had pressed it with your hands. It is the pressure of the air outside the bag that crumples it. When air is taken out of the bag, the pressure inside the bag becomes smaller than the pressure outside. The air outside pushes the sides of the bag in. The air has pressure.



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Why does the water rise in the medicine dropper? When the bulb is squeezed, air is pushed out of the dropper. (You saw the bubbles.) So when the bulb is allowed to swell up

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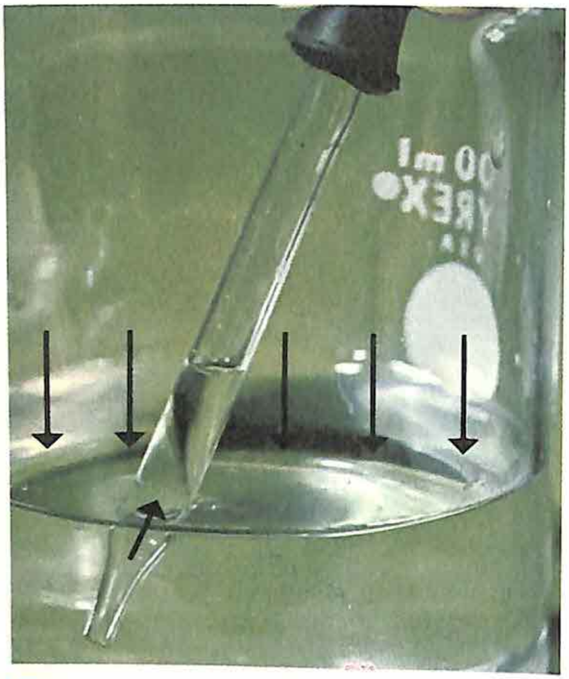

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again, there is less air in the dropper. This means that the pressure of the air left in the dropper is less than the pressure of the air outside. The pressure outside the dropper then pushes water into the dropper. The water rises. ■

The water rises because some air has been taken out. With this in mind you may be able to solve the puzzle of some disappearing molecules. See for yourself by doing the investigation on the opposite page.

Something Is Missing

As the steel wool rusts in the test tube, in the investigation, the level of the water rises in the test tube. ●

Why does the water rise in the test tube? Remember why the water rose in the medicine dropper. Part of the air in the dropper was taken out. Water rose in the dropper to take the place of the air taken out.

Water rises in the test tube for the same reason. Part of the air in the test tube has been taken out. *Some of the molecules have disappeared from inside the test tube.*

Where have these missing molecules gone? We will follow the trail of the missing molecules next. Before we do, however, try a little detective work on your own. What do you think has happened to the missing molecules of air?

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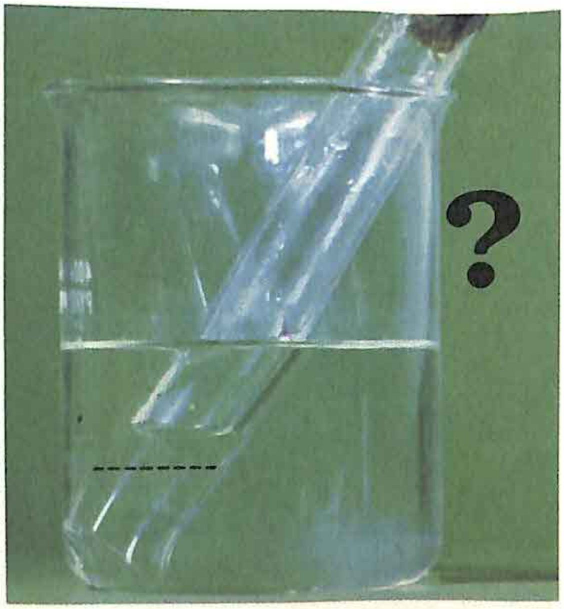


AN INVESTIGATION into Disappearing Molecules

Needed: a wad of steel wool, a large test tube, a pan of water, a marking pencil

Push the wad of steel wool to the bottom of the test tube. Do not pack the steel wool tightly, for air must be able to reach all parts of it. ■

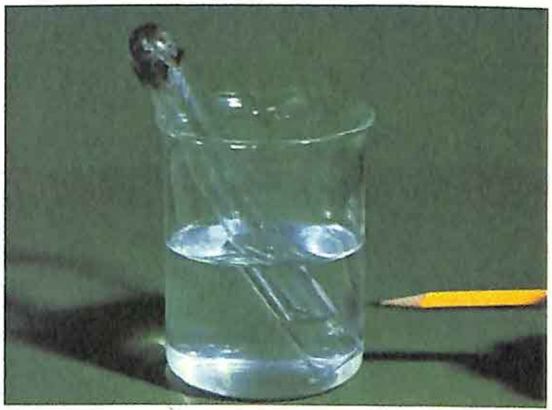
Fill the test tube with water, then empty it. This will wet the steel wool and the inside of the test tube.

Place the test tube upside down in the pan of water. ●

Leave the test tube in the pan of water for several days. Observe what happens to the steel wool and to the level of the water in the test tube. Mark the level of the water each day.

What happens to the steel wool? What happens to the water level? What happens to the amount of air inside the test tube?

Here is what happened during one trial. ▲ ◆



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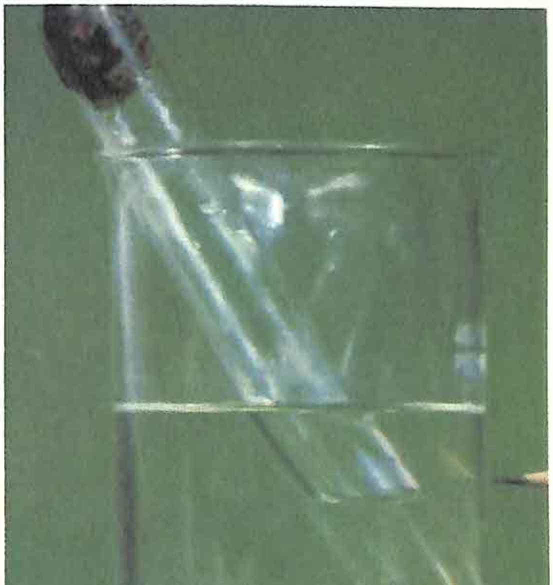

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BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A medicine dropper is squeezed in water. Then it is released. Water goes up into the medicine dropper because the water is

a. sucked up   b. pushed up

2. As the steel wool rusts in the test tube (in the investigation), the water rises in the test tube. The water rises because the air in the test tube is

a. increasing   b. getting less

USING WHAT YOU KNOW

Fill a test tube with water. Put your thumb tightly over the mouth of the tube. Put the mouth under water and take your thumb away. Why doesn't the water run out of the tube?

ON YOUR OWN

Air has a pressure of about 14.7 pounds per square inch. What does this mean?

Why does air have this pressure? Does it have this same pressure on a high mountain?

5. Finding the Missing Molecules

Steel wool rusts inside a test tube. As the steel wool rusts, the water rises. This shows that part of the air around the steel wool is being removed. Somehow, molecules of air are disappearing.

Rusting and molecules disappearing seem to be happening at the same time. Are rusting and disappearing molecules connected? Let us do some reasoning.

We know that rusting takes oxygen. When steel wool rusts, the iron in the steel wool combines with oxygen. ■

We know that air has oxygen in it. Air is a mixture of gases. One of the gases is oxygen.

Perhaps the rusting is taking molecules of oxygen from the air in the test tube. This sounds like a good guess.

But how good is a guess?

A Scientist's Guess

What good is a guess? Scientists often make use of guesses. Their guesses are a special kind, however, and have a special name. A scientist may call his guess a **hypothesis** (hy-POTH-eh-sis). A hypothesis is a *possible* explanation for something observed.

What is the difference between a hypothesis and an ordinary guess? It is this. When we say hypothesis instead of guess, it means that we intend to *test* our explanation. We intend to look for evidence that our possible explanation is right or wrong. In science we must test our explanations.

We guess that rusting is taking oxygen from the air in the test tube. Let us call this guess a hypothesis. We have a hypothesis that rusting is taking oxygen from the air in the test tube.

Now let us look for some evidence that this hypothesis is right or wrong. Let us see if we can **confirm,** or prove, our hypothesis.

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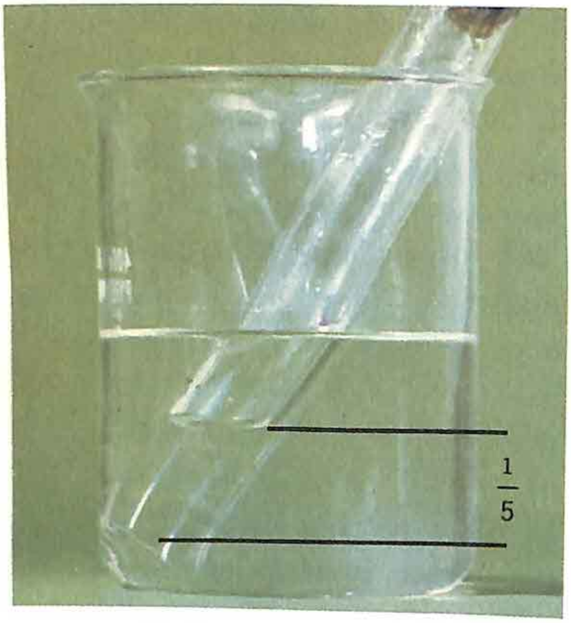

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One Fifth Is Missing

As the steel wool rusts in the test tube, the water rises. The water stops rising, however. It remains at one level. Did you observe this? The steel wool is not completely rusted, yet the water stops rising.

At this time, when the water has stopped rising, we can make another observation. Suppose we compare the height of the lost air with the height of the air to begin with. About one fifth of the air has been lost. ■ As often as this investigation is repeated, we will find that one fifth of the air has gone.

Do you happen to remember what part of the air is oxygen? One fifth of the air around us is oxygen. The other four fifths is made up of other gases.

Our hypothesis, or explanation, is that rusting is taking oxygen from the air in the test tube. If our hypothesis is right, how much of the air can rusting take? No more than one fifth, for only one fifth of the air is oxygen.

One fifth of the air in the test tube is missing every time we do the investigation. If rusting is taking oxygen from the air, this is what we would expect. Here is some evidence to confirm our hypothesis.

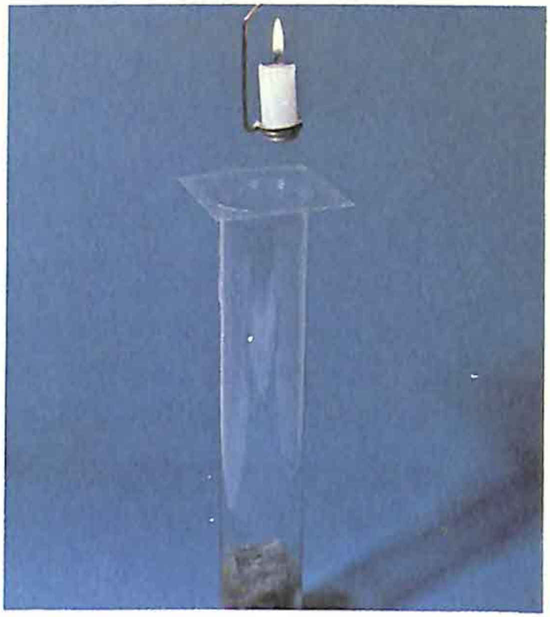
Another Check

Let us look for some more evidence for or against our hypothesis.

Suppose that all the oxygen in the test tube *has* been used up by the rusting of the steel wool. Would you expect a candle to burn in the air left in the test tube? No, for a candle must have oxygen to burn.

Here is a glass cylinder in which steel wool has rusted and the water has risen. A square of plastic is held tightly on the end under water, and the cylinder is turned right side up. No air from outside has got in. ●

Our hypothesis is that this cylinder has no oxygen in it. Now a lighted candle on a wire is lowered into the cylinder. What happens? ▲



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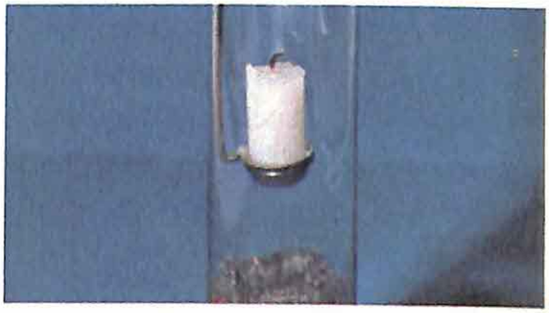


▲

The candle goes out at once. The candle behaves as if there is no oxygen in the cylinder.

Perhaps a lighted candle would not burn in such a cylinder, even if there were oxygen in the air? If a candle is lowered into ordinary air in the cylinder, it does not go out at once. It burns for a little while.

Here is more evidence to confirm our hypothesis, then. Because of this evidence, it seems more likely that our hypothesis is right, that rusting takes oxygen from the air in the test tube.

Does this evidence *prove* that our hypothesis is right? No. Scientists would ask for much more evidence than this. However, many other investigations have been done by scientists. A great deal of evidence has been collected. The evidence shows that the hypothesis is right. The rusting steel wool takes oxygen from the air.

The rusting steel wool takes oxygen molecules from the air. These oxygen molecules are combined with the iron in the steel wool. Thus the air has fewer molecules in it. The amount of air gets less.

You can see how useful a hypothesis may be. A scientist uses a hypothesis to find evidence. You can see, too, how useful a guess may be. A guess may lead to a hypothesis. Then the hypothesis may lead to a better explanation of what it is that puzzles the scientist. Or you.

Of course, sometimes a hypothesis turns out to be wrong. This doesn't always mean that it was a waste of time. A hypothesis that turns out to be wrong may help a scientist to find evidence for a correct hypothesis.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A scientist may guess at a possible explanation of what he sees. This possible explanation is a

a. conclusion   b. hypothesis

2. When the rusting steel wool in the cylinder has used up all the oxygen, the water should rise

a. one fifth of the way   b. four fifths of the way

3. A scientist uses a hypothesis

a. to find more evidence   b. instead of evidence

USING WHAT YOU KNOW

Scientists are exploring the Moon. From what they know of the Moon, their hypothesis is that there is no life on the Moon similar to that on Earth.

Could their hypothesis be wrong? Or is a hypothesis always right?

6. The Uses of Oxygen

Think for a moment about how important oxygen is.

Without oxygen, burning could not take place. Matches would not light. The fires that we use for cooking and heating could not burn, whether they were from coal or oil or gas or wood. The gasoline in the car and school bus would not burn, so cars and buses could not run.

Then, too, oxygen is one of the most important "building blocks" in the world. Oxygen combines with many different substances to build many different compounds. When substances burn, oxygen combines with carbon and makes carbon dioxide. Oxygen combines with hydrogen to make water. Oxygen combines with iron to make iron oxide. Oxygen combines with hydrogen to make compounds such as hydrogen peroxide. Oxygen combines with thousands of different substances to build useful compounds.

No doubt about it, oxygen is important. And there is a lot of this important substance on Earth. There is oxygen in the air. There is oxygen in the waters of the Earth. There is oxygen in the rocks and the soil of the Earth. This sandstone, for example, is mainly silicon and oxygen. ■

Of course there is another important use of oxygen to mention. All living things use oxygen in one way or another. *You* use oxygen. When you breathe in, you take in air. When you breathe out, you do not send out the same kind of air you took in. Of course, air you breathe out has more moisture in it than air you breathe in. But there is something else.

You inhale air with oxygen in it. In place of some of the oxygen you inhale, you breathe out a different gas, carbon dioxide. You do this with every breath. The air you exhale has more carbon dioxide in it than the air you inhale. The simple test in the investigation on the next page will show you.

■

AN INVESTIGATION into the Air You Breathe

Needed: a bicycle pump, two rubber balloons, two pieces of string, two glasses full of limewater

Fill one balloon with ordinary air, using the bicycle pump. Tie the balloon with a string. ■

Fill the other balloon with air from your lungs. Tie this balloon with a string. ●

Now put about half a glass of limewater into each glass. Let the air slowly and gently out of one balloon into the limewater in one glass. ▲ Do the same with the other balloon and the other glass.

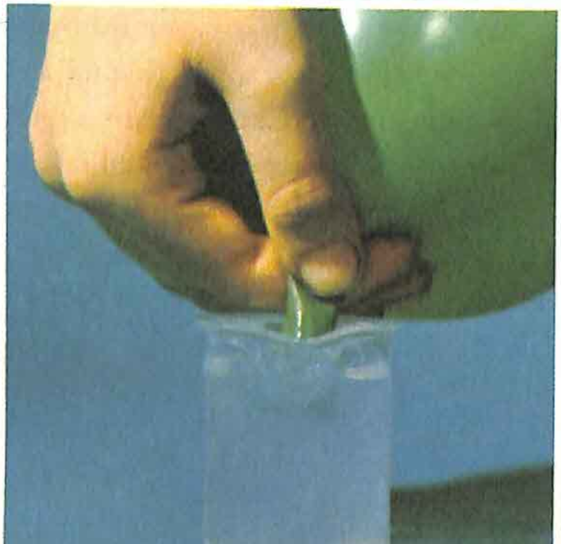
Here is what happened in one trial. ◆

Limewater turns a milky color when it meets carbon dioxide. Which air turned the limewater milky? Why?

■

●

▲



◆

What You Do with Oxygen

As a candle burns, it takes oxygen from the air. The wax of the candle contains the element carbon. As the candle burns, it takes this carbon and combines it with oxygen. It gets the oxygen from the air. ■

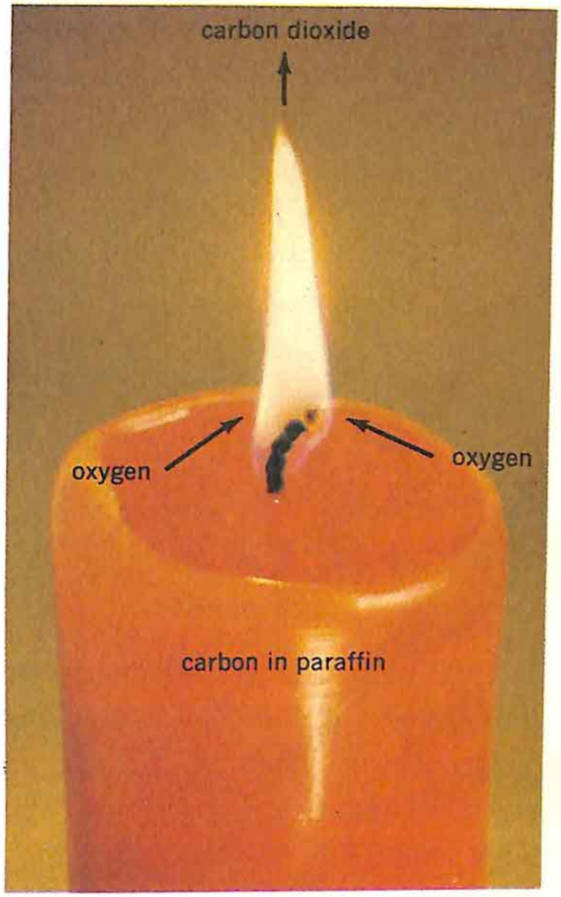
As the candle combines carbon and oxygen, it produces light energy and heat energy. Perhaps you have already guessed what the candle combines carbon and oxygen into. The candle combines carbon and oxygen into carbon dioxide.

carbon + oxygen ⟶ carbon dioxide + energy

The energy is heat and light energy.

A burning candle takes oxygen from the air and gives off carbon dioxide. *You* take oxygen from the air and give off carbon dioxide. A burning candle makes carbon dioxide by combining carbon and oxygen. *You* make carbon dioxide by combining carbon and oxygen in your body. Where do you get the carbon? From the food you eat. Sugar, bread, meat, and milk, all have carbon in them. Where do you get the oxygen? You breathe it in, of course.

A burning candle gives off energy. Do *you* produce energy? Put your hand on your mouth. Breathe out. Your breath is warm. The heat which made your breath warm is produced in your body.



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In a burning candle,

carbon + oxygen ⟶ carbon dioxide + energy

In your body,

carbon + oxygen ⟶ carbon dioxide + energy

Does this mean, then, that burning is taking place in your body? No, not in the usual sense of burning with a flame. Heat, but no light, is given off by the **chemical reaction** in your body. Whenever a compound is broken down into other substances, or new compounds are built up, we say a chemical reaction has taken place. You will meet many such reactions.

Carbon and oxygen are combining now in your body, as you read this. Energy is being produced. However, this is not the only way you produce energy. There are many other chemical reactions in your body that give you energy. You will learn more about some of them later.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A burning candle uses up
   a. carbon dioxide b. oxygen

2. Compared with the air we breathe in, the air we breathe out has
   a. less carbon dioxide b. more carbon dioxide

3. Carbon and oxygen are combining now in your body to produce
   a. heat energy b. light energy

USING WHAT YOU KNOW

In a candle, and in our bodies,

carbon + oxygen ⟶ carbon dioxide + energy

What happens to the energy from a candle? What happens to the energy from our bodies?

ON YOUR OWN

Probably compounds with carbon in them are burned every day in your home. Where are they burned? When are they burned?

7. The Return of Oxygen

We are using up the oxygen in the air. Oxygen is being used up every time we take a breath. Oxygen is being used up every time every animal takes a breath. Every time every fish passes water through its gills, oxygen is being used up.

Every time a lump of coal or a piece of wood is burned, oxygen in the air is used up. Whenever oil or gas is burned, oxygen is used up. Every automobile engine is using up oxygen as it burns gasoline.

Oxygen is combining with other elements, too. For example, rusting is using up oxygen.

Oxygen in the air is being used up all the time. It seems that it should have been all used up long ago! Yet there still is plenty of oxygen in the air.

It must be that oxygen is being put back into the air somehow. But how is it being put back?

A Green Plant in a Jar

🟦

In the year 1750 an English scientist named Priestley (PREEST·lee) put some green plants under glass jars. 🟦 Nothing could get in or out of the jars. Priestley found that the green plants grew inside the glass jars when they had light. They did not grow if they did not have light. In the dark the plants soon died.

Priestley decided to try the same sort of investigation with an animal. Could an animal live in a closed glass jar, like a green plant? He put a mouse in a jar. Nothing could get in or out. He soon found that the mouse could live only a little while in the closed jar. After a while the mouse began to get sleepy. Soon it went to sleep. If it was left too long in the jar, the mouse died.

Priestley found a strange thing though. He found that if he put a green plant in the jar with the sleepy mouse, the mouse soon began to move about. The mouse became lively again!

By doing these investigations and other investigations as well, Priestley concluded that green plants give something to the air around them.

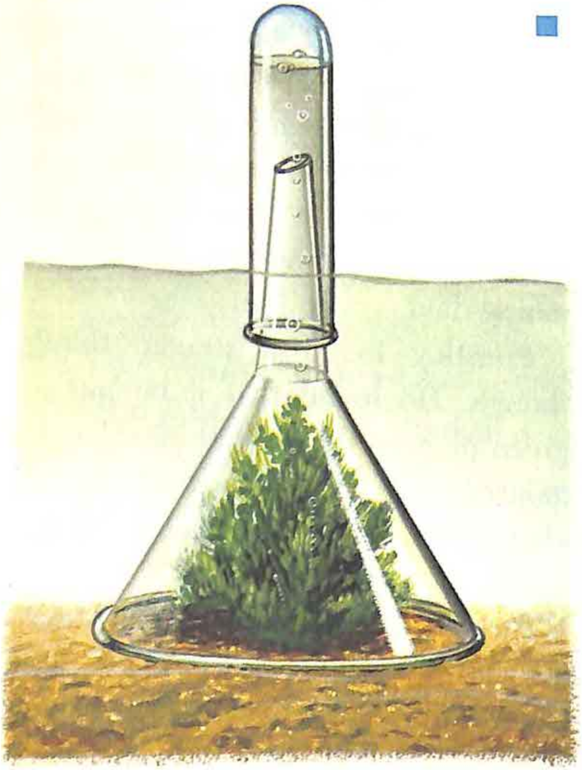
He also found that green plants do this in the light, but not in the dark.

What could a green plant give to the air that would make a sleepy mouse lively again? You may want to make up a hypothesis of your own. The investigation on the opposite page may furnish some evidence. Try it.

The Gas a Green Plant Makes

The green water plant called *Elodea* (ih·LOH·dee·ah) gives off bubbles when light is shining on it. When elodea plants are in the dark, the bubbles slow down and stop.

■



There is gas inside the bubbles, so this green plant is giving off a gas. We are able to see the gas being given off because the plant is under water. This green plant gives off a gas only when light is shining on it.

What is the gas that the elodea plant gives off in light? Here is a way of collecting the gas, so that it can be tested. ■ It is difficult, however, to collect pure oxygen. But when the gas is collected and tested, it turns out to be mostly *oxygen.* The plant gives off oxygen when light is falling on it.

Scientists have done many experiments which show that when light is falling on this green plant, *Elodea,* the plant gives off oxygen. Many other investigations and experiments by scientists have shown that all green plants do the same thing. *All green plants give oxygen to the air, when in the light.* The green plants use the energy of light to do this.

Now the mystery of the sleepy mouse that became lively again can be explained.

In the jar by itself, the mouse soon used up the oxygen in the jar. The mouse became sleepy. It needed oxygen. When a green plant was put in the jar, the mouse became lively again. The green plant gave off oxygen and the mouse used it.

AN INVESTIGATION into a Plant Under Water

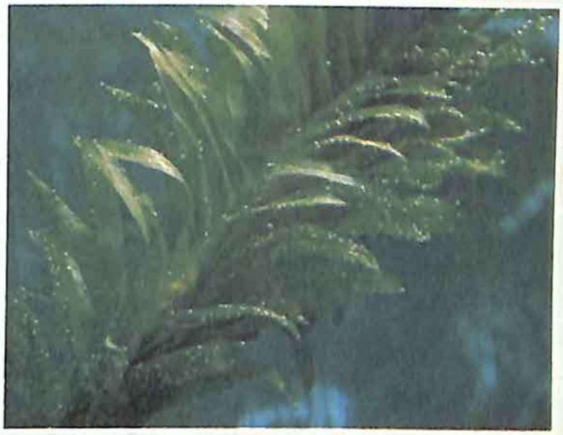
Needed: an aquarium with healthy elodea plants and fish, some pieces of cardboard

Aquarium plants and fish are healthy if they are growing well. Let the elodea plants float on the water. ■ Place the aquarium in sunlight. Observe the plants. From time to time you may see something like this. ●

Watch the bubbles rising. Then shut off the sunlight from the elodea plants with the pieces of cardboard. ▲

What happens to the bubbles when light is cut off? Here is what happened in one trial. ◆

■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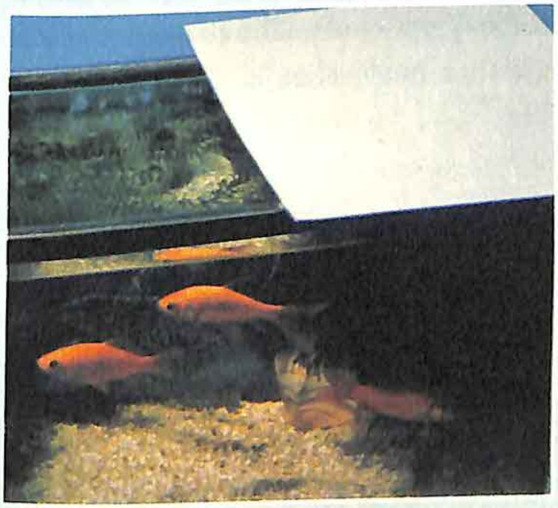
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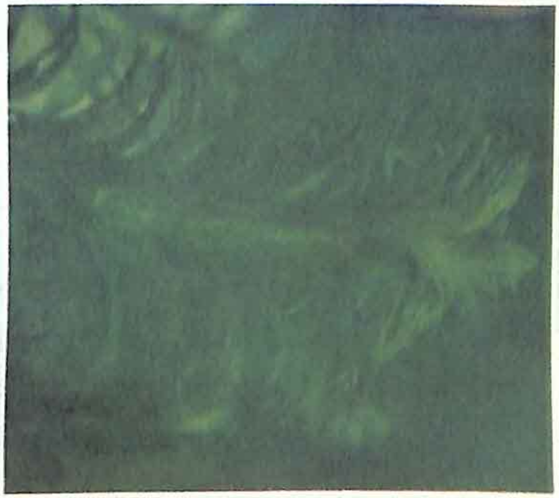
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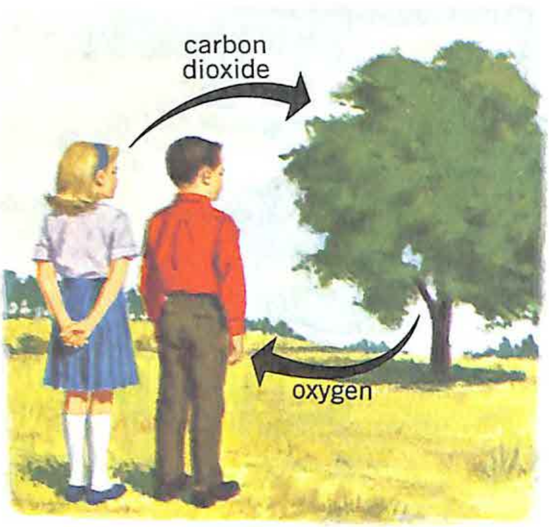

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Now the mystery of where *our* oxygen comes from can be explained. Although we are taking oxygen from the air, green plants are putting oxygen back into the air. They do not do this all the time, however. They do it only while light is shining on them.

Where does this light come from? It comes from the Sun, 93 million miles away. We depend on something 93 million miles away for the oxygen we breathe.

Another Cycle

It might seem that we have reached the end of this story. We have found out where the oxygen we use comes from. The story is not over, however. In a way, it never ends. Let us see why this is so.

If there is a green plant in view, take a good look at it. You and that green plant are partners in living. You need oxygen. The green plant gives off oxygen. You give off carbon dioxide. *The green plant takes in carbon dioxide.*

Whatever is burning now is using up oxygen, and it is also making carbon dioxide. Green plants are taking that carbon dioxide and making oxygen, which they put back into the air.

All this can be summed up neatly in a diagram. ■ Do you recognize this? It is a cycle. This one is called the **oxygen cycle**. The oxygen cycle is another cycle that is a part of your life.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Every time we breathe in, we use up
   a. oxygen b. carbon dioxide

2. Oxygen is put back into the air by
   a. green plants b. animals
3. When giving off oxygen, a green plant uses up
   a. oxygen b. carbon dioxide
4. A green plant can use energy from
   a. coal b. the Sun
5. All green plants give off oxygen to the air
   a. in the light b. all the time

USING WHAT YOU KNOW A cow in a green field uses the grass for food. What else does the grass give to the cow? What does the cow give to the grass?

8. The Main Concept: An Important Cycle

A crab crawling at the bottom of the sea is under an ocean of water. *You* are moving at the bottom of the atmosphere, under an ocean of air. The crab must take in water to live. You must take in air to live.

What is this important stuff you must breathe? Air is a mixture of different gases. It is made up of molecules of different substances.

Some of these molecules in air are elements—that is, they are molecules made up of one kind of atom. Oxygen is an element in the air. Some of the molecules in the air are compounds made up of different atoms. Carbon dioxide is a compound in the air. Air is a mixture of elements and compounds.

We know that one element in air is very important to us. It is oxygen. The oxygen in the air we breathe is used in our bodies. In our bodies the food we eat is combined with the oxygen we breathe. The result is energy, energy that makes us alive. Food is not enough. Our bodies cannot use food without oxygen.

Oxygen is important in other ways as well. Fuels such as coal and gasoline and oil and gas cannot burn without oxygen. When oxygen combines with carbon, the result is energy.

We use oxygen. Burning fuels use oxygen. Living things use oxygen. Living things combine oxygen with carbon and get energy for living.

One thing is very clear about this important substance. Oxygen is being used at a great rate.

All the oxygen ought to have been used up long ago.

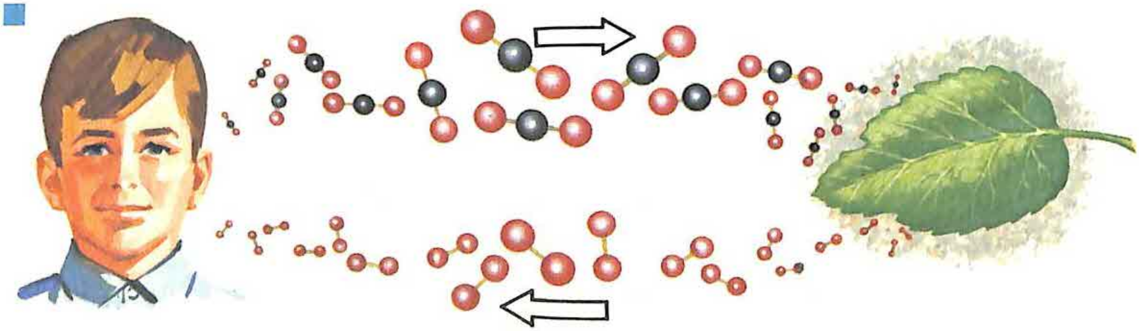
There Is a Cycle

The oxygen in the air is being used in many ways. Yet the oxygen in the air has not been used up. Oxygen is still in the air because it is being put back by green plants. Green plants give off oxygen when they are in light. We depend on green plants not only for food but also for this important substance, oxygen.

What does a green plant use when giving off oxygen? Carbon dioxide. Where does the carbon dioxide come from? We and other living things give off carbon dioxide. When we combine oxygen and carbon in our bodies for energy, we make carbon dioxide and then breathe it out. Animals take in oxygen and give off carbon dioxide. In the foodmaking process green plants take in carbon dioxide and give off oxygen.■ There is a cycle, then. Because there is a cycle, oxygen is not used up. The oxygen molecules you are breathing in right now, you will combine with other molecules into carbon dioxide molecules and breathe out. Some green plant will take in those carbon dioxide molecules you made. Then that green plant will give off oxygen molecules to the air. Those oxygen molecules may be used again. And again. And again.

The oxygen in the air is not used up because there is a cycle. You and every other living thing are a part of the oxygen cycle.

■



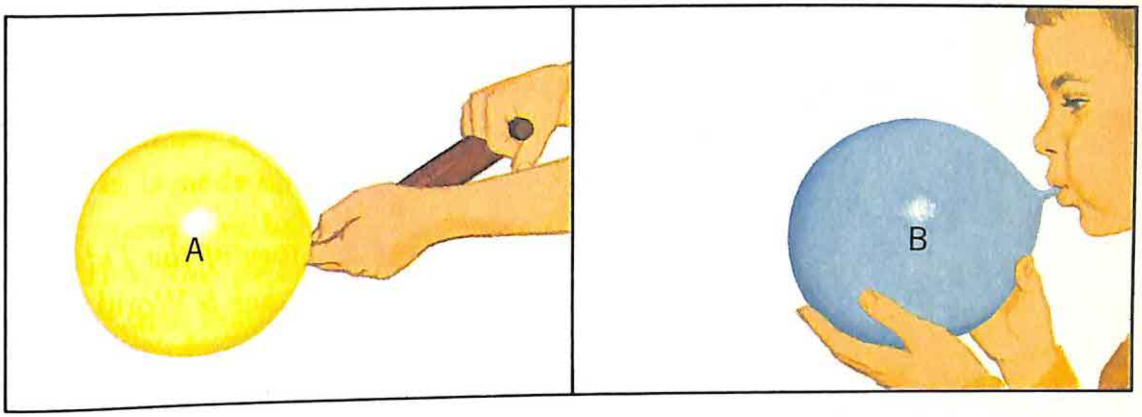
Fixing the Main Concepts

TESTING YOURSELF

Study the statements below and choose the correct responses. Your study will help fix in your mind the main concepts of this unit.

1. Balloon B has more of one gas than balloon A. That gas is

a. oxygen b. carbon dioxide



2. Balloon A has more of one gas than balloon B. That gas is

a. oxygen b. carbon dioxide

3. If balloon A were emptied into limewater, the limewater would

a. remain clear b. become milky

4. If balloon B were emptied into limewater, the limewater would

a. remain clear b. become milky

5. Balloon A, compared with balloon B, has more of the element

a. oxygen b. carbon dioxide

6. Balloon B, compared with balloon A, has more of the compound

a. oxygen
b. carbon dioxide

7. If a green plant were put in balloon B (in light), the plant would soon use up most of the

a. carbon dioxide
b. oxygen

8. An animal like a mouse would live longer in

a. balloon A
b. balloon B

9. A mouse in balloon A would soon use up the element

a. oxygen
b. nitrogen

10. When different elements combine, they form

a. compounds
b. atoms

FOR YOUR READING

The Rise and Fall of the Seas—The Story of the Tides, by Ruth Brindze, published by Harcourt, Brace & World, 1964. How the Sun and the Moon draw up the oceans to make tides, how tides are measured and predicted, how men have made use of tides, and many other interesting things about the great waters on the Earth.

GOING FURTHER

In the investigation on page 125, the green plant elodea gave off bubbles in light. In the dark the plant stopped giving off bubbles.

Suppose you were to cover the aquarium completely with red cellophane or red plastic. Would the plant still give off bubbles?

Would it give off more or fewer bubbles under yellow cellophane? green cellophane? blue? orange?

Plan an investigation to see under which kind of light the elodea plant produces the most gas bubbles.

A New View of Matter

How many different kinds of matter are around you right now?

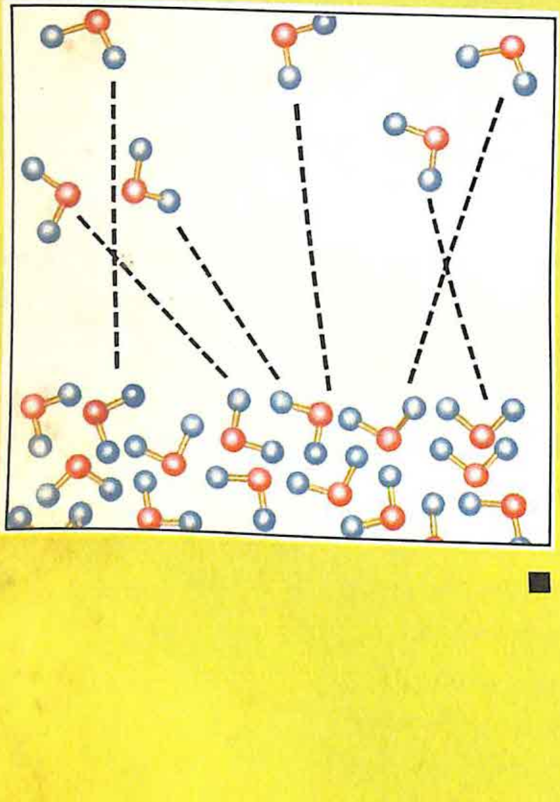
Some are gases, like the gases in the air you are breathing. Some are liquids, like the water you drink. Some are solids, like the paper of this book. What different kinds of matter there are!

Yet we know that all matter is alike in this: all matter, whatever kind it is, is made up of tiny particles.

The gases you breathe, the water you drink, the paper of this page—most of the matter around you is made up of the tiny particles we call molecules. A molecule is the smallest part of a substance that still has the properties of that substance. A molecule of oxygen, for instance, is the smallest part of oxygen that still has the properties of oxygen. A molecule of water is the smallest part of water that still has the properties of water. ■

Yet the tiny particles we call molecules are made up of still smaller particles. Molecules are made up of particles that we call atoms. Some molecules are made up of atoms that are all the same kind. Some molecules are made up of different atoms.

■



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For instance, a molecule of oxygen is made up of two atoms bound tightly together. The atoms are alike. Since the two oxygen atoms are alike, oxygen is an element. An element is made up of only one kind of atom.

A molecule of water, however, is made up of different kinds of atoms. It has two atoms of hydrogen and one atom of oxygen, all tightly bound together. Water is a compound, for a compound is made up of atoms of different elements. The elements in a compound are not simply mixed together. They are tightly bound together by forces. They are chemically combined.

Particles and Changes

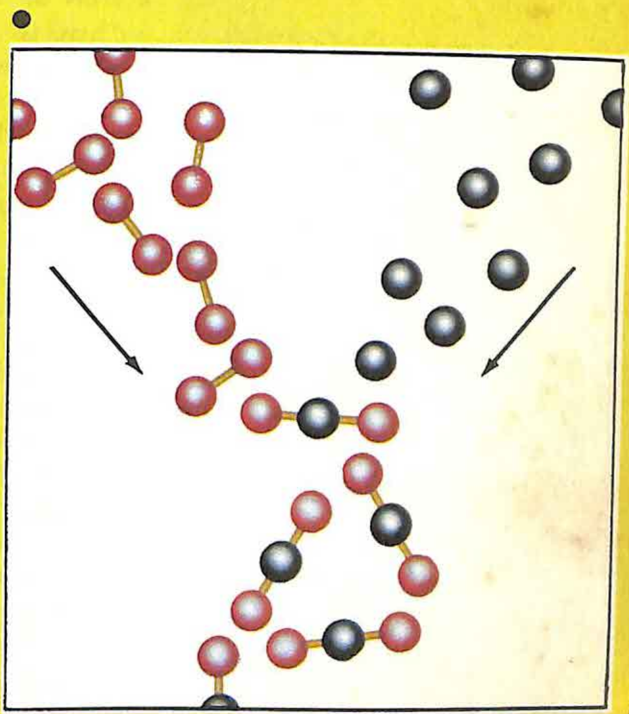
Matter is made up of particles, of arrangements of molecules and atoms. But these arrangements are not forever fixed and unchanging.

Put a drop of water on a plate, for example. Little by little the drop gets smaller, until it disappears. The drop of water evaporates, of course. The water changes from a liquid to a gas. The water molecules move away from the drop into the air. ■

As the water becomes a gas, the molecules are able to move around much more freely than they could in the liquid. Notice, however, that the molecules themselves have not changed. Each molecule is still made up of two atoms of hydrogen and one atom of oxygen. Each molecule is still a water molecule. Its atoms have not changed. The space between the molecules has changed: the molecules have moved around and taken a different position. This change from liquid to a gas is a physical change. Water that evaporates undergoes a physical change.

There is another important kind of change for particles. As you breathe in now, you are taking in molecules of oxygen. As you breathe out, you are sending out molecules of carbon dioxide. The molecules of oxygen that you breathe in are taken apart into atoms of oxygen in your body. Then these atoms of oxygen are combined with atoms of carbon (which you get from food) to make new molecules, molecules of carbon dioxide. So new molecules are formed out of the particles of the old ones. ●

When atoms of oxygen and atoms of carbon combine to form molecules of carbon dioxide, this is a chemical change. Molecules can take part in a physical change or a chemical change. Matter can be changed because the particles of which matter is made up are in constant change.



CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

Unit Five

THE FALL OF A TREE

(Text pages 134–73)

UNIT CONCEPT

Living things capture matter from the environment and return it to the environment.

A Preview of the Concepts

Children recognize that the environment of a plant includes other plants and animals as well as soil, water, and light. They gradually become aware that there is a cycle of use of matter by plants and return of matter to the environment.

A VIEW OF THE UNIT

There are several ways to approach an understanding of green plants. One is the ecological approach, the one used here. It is especially useful for young children, who are naturally curious about living things and how and where they grow. What's this? Why do seeds sprout? What makes them grow? These are some questions children quite often ask. The ecological approach focuses their curiosity on the concept of interdependence between living things and their environment. In later courses, they may study living things around the concept of the cell, its structure and its organization in a plant or an animal; or they may study the interchange of matter and energy as the cell breaks down and recombines molecules for the life processes of the organism.

Children start this unit by trying to grow seeds under varying conditions. They observe that different plants need different environments to get the substances they need.

Children then question from which part of its environment a green plant gets these substances. They discover that only a minute, though vital, part comes from the soil and that the rest of the substances come from water and air.

Children begin to understand how a green plant utilizes the substances taken in for its growth processes. They begin to recognize the cells of the plant as the tiny factories in which chemical changes of these substances take place.

Up to now, the young inquirer has investigated the plants and animals he already knows a good deal about. He now turns to more abstract concepts of cellular and molecular changes within these organisms. Thus, once a child wishes to know just how a tree "stays healthy," and exactly what it needs to "grow so big," he is ready to find out something about the kinds of molecules a tree takes in, and how and where these molecules are changed within the tree.

Children then discover that when a green plant dies, the substances it has taken in are returned to the environment. As children become aware of these cyclical processes, they may recognize that the concept of chemical change in nonliving matter applies also to living matter.

As a growing plant lives, it removes substances and energy from its environment and, as it decays, it returns these to the environment in another form. Matter and energy are neither created nor destroyed, but only changed in form.

Ecological Approaches

Ecologists have different ways of analyzing the relationships between organisms and their habitat. They may ask: Which are the *producers,* which the *consumers?* A cow munching on grass seems obviously a consumer, but the ecologist continues to study the scene and finds that the cow, too, is a producer in some ways.

Or the ecologist may ask: What is the *food chain* here? He discovers, perhaps, that larger animals are predators on smaller, the smaller on those still smaller, and so on, until the final link in the food chain is, inevitably, the green plant.

Again, he may ask: What are the *adaptations* of these plants and animals? Here he seeks to understand the special structures that enable organisms to live within their particular environments.

Any of these methods of analysis may be used productively with children if they are made aware that each method is concerned in the end with: How are organisms getting their supply of matter and energy? What energy and matter are they supplying to other organisms?

In general, each child will be able to plan and carry out many ecological inquiries on his own. For the most part, he needs no elaborate equipment but simply his five senses and his neighborhood. At home, a goldfish bowl moved into or out of the light, a plant moved to or from a hot radiator, and other similar situations readily provide the conditions of a useful investigation. These offer environments in which living organisms may be deprived of necessities for a few days without serious injury to them. At the same time, they are yielding useful data from which children may form concepts.

Collecting leaves, stems, soils, and so on, are ways that may be used to make children aware of the great diversity among living things and of their adaptive structures. Moreover, the powers of observation of children will be refined and library research will be encouraged as they attempt to identify their collected objects.

Most important, the collections may be used as an approach to the big ideas, the main concepts. The probable events in the lives of these collected objects should be stressed more than their labeling. Where was the living tree growing from which this leaf was picked? What kind of soil, sunlight, and moisture were in that spot? Did the tree seem to be growing well? Why, or why not?

No special knowledge of botany or zoology is needed to lead the class on worthwhile discovery hikes. If children wish to know the name of a particular plant or animal, they need simply to observe, record, and then refer later to a book; it is not necessary for the teacher to "know all." They need the teacher, instead, to invite them to think speculatively and conceptually about organisms they see, keeping always in mind the processes common to all organisms.

SUPPLEMENTARY AIDS

All films and filmstrips are in color and on the intermediate level of comprehension and concept formation, except those rated as "Primary." These are relatively less difficult for the grade. Names and addresses of distributors and suppliers are on page F-25.

Films

How Plants Grow (11 min., sound), Cenco, 1964. Explains that although plants look different, they are alike in many ways, and the functions of the parts are the same; how plants make food from air and water, using energy from sunlight; the life cycle of the plant is clearly developed.

Planting Our Garden (11 min.), E.B.F. Illustrates the basic requirements of plants for growth; shows the effect of soil, sun, water, and seasonal growth.

Living Plants (11 min.), E.B.F., 1965. Covers the main plant groups; the parts of a flowering plant; how green plants make food. A simple chemical concept of photosynthesis is developed.

How Plants Help Us (12 min.), McGraw-Hill. Shows how all living things depend on plants in one way or another—as food for animals and as food, shelter, and other essentials for man.

Life on a Dead Tree (11 min.), F.A. Examination of a dead tree shows that it is providing a home and food for many different kinds of animals and plants; lizards, insects, and fungus plants.

Filmstrips

How Plants Start Growing (44 frames), E.B.F., 1962. Shows how plants grow from seed, cuttings, etc.; how water, air, and soil are necessary for growth; that the new plant will be the same kind of plant as the parent plant.

How Plants Help Us (44 frames), E.B.F., 1962. Shows how all living things depend on plants; how they protect soil from erosion; how they give off water and oxygen and absorb carbon dioxide.

Animals and Plants of the Forest (38 frames), McGraw-Hill, 1961. Each type of environment has its own related animals and plants; how a dead tree may support a small community of living things.

Soil Is for Growing (43 frames), McGraw-Hill, 1963. Demonstrates that each plant grows best when it receives a proper amount of sunlight, water, and suitable soil; suggests investigations into effects of soils on plant growth.

How Trees Grow (43 frames), McGraw-Hill, 1963. How a tree, a green plant, grows roots down and stem up; how it makes and stores food; how from green plants comes all of the food and the energy supply for all living things.

Plants and How They Grow (58 frames, sound), S.V.E., 1964. Shows how roots take up water and minerals for the plant; how leaves, with the help of the Sun's energy, change water and carbon dioxide into food; shows the life cycle of a plant.

(The next three short filmstrips are excellent for a beginning study of plant life.)

Green Plants Are Important to Us (25 frames), Jam Handy, 1964. All living things depend on green plants; they provide both direct and indirect sources of food, also building materials, clothing, and fuels. (Primary)

How Green Plants Grow (25 frames), Jam Handy, 1964. Drawings show how roots absorb water and minerals; how leaves absorb carbon dioxide from air; how they make food; life cycle of a plant. (Primary)

What Do Green Plants Need for Growth (25 frames), Jam Handy, 1964. Investigations show that green plants grow best when they have the *correct* amount of light, water, sunlight, and fertilizer. (Primary)

Science Reading Table

Starred (*) titles are especially recommended for content and reading level. Names and addresses of the publishers are on page F-24.

***The Community of Living Things in Forest and Woodland,* by Stephen Collins, Creative Educational Society; in cooperation with the National Audubon Society, New York, 1956. Volume four of five volumes. Full-page photographs accompany each page of text. A comprehensive study of the interrelationships of plants and animals in a virgin forest and deciduous, evergreen, redwood, cypress, and mangrove forests. (Advanced)

***The Forest,* by Peter Farb and the editors of *Life,* Time, Inc. From the *Life* Nature Library, Silver Burdett, 1964. Remarkable photographs, many in color, exemplify environments provided by forests around the world. The plants and animals that live in forests, and the structure and growth of trees as the dominant plant. Teachers and pupils will enjoy using this book together. (Advanced)

The Forestry Story, by George Shaftel and Helen Heffernan, from the *Man Improves His World* series, L. W. Singer, 1963. An exciting story of a forest fire introduces the factual information which comprises the major portion of the book. In addition to a section on modern methods of combating forest fires, it describes timber resources, forestry conservation programs, the production of new and improved kinds of trees, and forest enemies. (Advanced)

***Grasses,* by Irmengarde Eberle, Henry Z. Walck, 1960. The importance of grasses to people around the world is the theme of the book, but the narration includes a description of different kinds of grasses. Wild as well as cultivated grasses are included. (Average)

How a Seed Grows, by Helene J. Jordan, Crowell, 1960. Slow-paced description of every detail of the sprouting of a seed. A seed-sprouting investigation is described in words and pictures. (Easy)

Plants That Move, by Millicent E. Selsam, William Morrow, 1962. The first section describes the movements of leaves and flowers and the second describes those of vines. Easy-to-do investigations and excellent drawings show what happens when plants move. (Average)

The True Book of Bacteria, by Anne Frahm, Childrens Press, 1963. Questions about bacteria are answered with brief statements. What are they? Who discovered them? What do they look like? How do they grow? Where are they found? When do they help us? When do they hurt us? How can we get rid of them? How can we learn about them? Are they important in outer space? Presents basic facts about bacteria. (Average)

What Is a Plant, by Gene Darby, Benefic Press, 1960. The growth of a plant from seed to flower is stated briefly. The likenesses and differences among different kinds of plants are described by words and pictures. The use of plants as food and fiber is touched upon. (Easy)

°*What Is a Tree,* by Gene Darby, Benefic Press, 1957. Describes tree growth from a seedling to a mature tree. Seasonal change and tree products are described with words and pictures. (Easy)

▶ INTRODUCING THE UNIT

One way of inviting interest is to place on your desk, as the children watch, a glass of water and a closed, empty jar, saying:

"Here is an ordinary glass of water. It is not really ordinary though. It contains some things that you cannot see. What do you think they are? (Minerals.) And here is a bottle of air. How long do you think *you* could live if you had only water to drink, air to breathe?"

Invite the children to speculate freely on this question and to revise each other's speculations. Then continue: "And how big do you think you could grow if you had just the water and air to live on?"

After children have had the opportunity to discuss this, have them turn to the unit opening picture (page 134). Point out that the oak tree in this picture lived over 200 years on just water and air and a little bit more. And the oak tree grew over 100 feet tall on just water and air. How is this possible? In this unit, we will find out how the oak tree was able to do this, and where it had to live to do so.

(Text pages 136–40)

SUBCONCEPT

Living things are dependent on a particular environment.

Section 1: WE GROW A PLANT

Children become aware that different plants need different conditions of soil, water, and sunlight in order to grow.

Introducing the Concept

Have you ever seen a terrarium? What would we need to make one? If necessary, clarify that a terrarium is a container for growing *land* plants and animals, just as an aquarium is for growing *water* plants and animals. As children plan a classroom terrarium (See *A Sourcebook for Elementary Science*, pages 81 ff), they will develop an interest in the important concepts of this section. One child may bring a cactus or other desert plant. Another may bring a fern or other moisture- or shade-loving plant. Will they grow well in the same terrarium? Why?

Equipment and Materials

. . . terrarium
. . . cacti or other desert plants
. . . water, bog, or garden plants
. . . packages of seed

You could also start with an out-of-doors observation. What kind of plants can we see from the window? Are there orange trees growing in your neighborhood? Are there pine or spruce trees? Why not?

The planting instructions found on seed packages may be read to children. They will note that the directions are different for different kinds of seed. You are ready to ask a key question.

Why can't you just put seeds in soil and let them grow?

Developing the Concept

Green plants need the right conditions for growth.

Investigation. As children read the first two paragraphs (page 137), invite hypotheses on the question: Is it really easy for a seed to grow? The children may recall experiences with garden or potted plants. This leads into the investigation on text page 136.

Processes emphasized

Observation
Analysis of observations
Investigation (with design of experiment)
Analysis of ways of the scientist
Hypothesizing
Theorizing
Prediction
Field trip

Since it will take time for the seeds to sprout and grow, children should be encouraged to study the pictures of one trial (page 136) and to form hypotheses which will be tested by their own later investigations. How does the growth of seeds 1, 2, 3, and 8 differ? Why do you think it differs? What conditions were exactly the same for all four seeds? If the seeds seem different in growth, what condition may we then *suspect* is the reason for this? (The watering. Seeds 1 and 8 may have had too much water; seed 3 probably had not quite enough; and seed 2 seemed to have just the right amount.) Refer to the table on page 137.

If the children agree too quickly, ask: How can we be sure? What conditions, other than water, might also be influencing the growth? Is one plant nearer a hot radiator, for instance? Is just one investigation enough? Emphasize that scientists do an experiment over many times and compare their results before they decide what the results mean.

Equipment and Materials

See text page 136; also the Teacher's Manual for *Classroom Laboratory 4.*

Children should now compare seeds 4, 5, and 2 (only the light is different); seeds 6 and 7 (only the soil is different). Seed 4, deprived of all light, has grown an abnormally tall stem, and has been unable to develop its green matter. Seed 5, grown in the shade, also has an abnormally tall stem and its leaves have not developed well.

Why is it important to compare plants in which *all* conditions of growth are exactly alike except the one condition whose effect you are studying (called the *variable*)? Could you tell which condition made the greatest difference in how plants 3 and 4 grew? (No. Each had different light or each had different watering.)

Encourage children to plan the growing conditions for seeds 9, 10, and 11 (as indicated in the chart on page 137) so that they vary only one condition.

The environment of a living thing includes all surrounding conditions that affect its growth. Different plants have adapted to different environments.

Equipment and Materials
- . . . cactus
- . . . common flowering plant

Is there one environment that is right for all plants? Upon completing this section, children may define the term *environment* in their own words and decide that a "right" environment for a particular living thing is one in which it can get the substances it needs.

Hold up a cactus plant and a common flowering plant with large leaves or pictures of these plants. Ask children to compare the "leaves." The leaves of the cactus plant are just the tiny spines; the fleshy parts are stems. Since a plant loses water through its leaves, how do such tiny leaves protect the cactus for living in its desert environment?

The fleshy stem of the cactus can store water for long periods. How do the stems of the other plant differ? Would you expect it to be able to live in the desert? Children suggest other plants adapted to live under other conditions, such as light or shade, sand or loam. They infer, correctly, that a right environment for one plant is not necessarily the right environment for another.

Extending the Concept

Equipment and Materials
- . . . old sheeting
- . . . bird or chicken seed
- . . . rubber bands
- . . . large pan
- . . . felt-tipped marker

Other influences that affect seed growth. Children will enjoy setting up a "rag-roll seed tester." Mark off and cut a strip of old sheeting into 4-inch or 5-inch squares. Each child or group of children places about ten seeds (bird seed or chicken feed) on his square. Cover each square with another strip of cloth. As each child carefully rolls up a square, fasten the roll with rubber bands. Label each rag roll with a child's name and the name of the seed, if identified.

Dampen the rolls and set them on end in a pan of shallow water. Every few days or so, have children carefully unroll their squares and observe the results. Do all the seeds sprout equally well? Can children think of reasons why not? Occasionally a seed will not sprout under any condition. Compare the results with those on page 136.

Children may be able to bring in seed-package labels which include the per cent of germination expected if the seeds are planted within a reasonable time. How often is it 100 per cent?

Nursery or greenhouse visits. Many children have house or garden plants. What growing conditions are best for these plants? What kind of authority would you talk to? If you plan to arrange a visit to a cooperative nurseryman, encourage preparation of questions to ask him. Let the children appreciate that clearly stated questions save their time and the nurseryman's, and they will get more information.

Equipment and Materials
- . . . jar and lid

Building miniature terrariums. In a nearby wood or field or from the backyard, each child may remove a patch of grassy or mossy land about 1 inch square and as deep, and place this in the tin lid of a kitchen jar, with the jar inverted over it. Each child carefully studies the place from which he removed the patch of land to determine the conditions of light, moisture, and temperature which he must maintain for his miniature terrarium. He keeps a record of exactly what he has done, how the bit of land thrives, and his reasons for its thriving or failure.

Reviewing the Concept

(Text pages 139–40)

Before You Go On. 1. b 2. a

Using What You Know. 1. The cactus lives in the desert where it thrives on strong sunlight and only intermittent, rare rain; the sugar maple will flourish and grow to full height in areas with favorable temperatures, rich woodland soil and adequate rainfall or remain as small as a shrub in colder, rocky areas of poor soil. 2. Food, water, warmth, air.

Section 2: THE SCIENTIST AND THE WILLOW TREE

(Text pages 140–46)

SUBCONCEPT

Green plants get the matter for growth from water, soil, and air.

Children question from which part of its environment a green plant gets the substances it needs. They become aware that a small but vital part comes from the soil, the rest from water and air.

Introducing the Concept

Processes emphasized

Observation
Analysis of observations
Design of investigation (with experiment)
Hypothesizing
Theorizing
Recording

Equipment and Materials

See text page 143; also the Teacher's Manual for *Classroom Laboratory 4.*

Probably the children have a general idea of where green plants get the substances they need for growth and development. You may wish to check by asking what green plants need. (Air, water, soil.) What else? It comes from 93 million miles away. (Energy from the Sun.) What makes a tree grow so big and heavy? Does the weight of a tree, a potato, or an apple come mainly from soil, or water, or air? Let the children suggest their hypotheses and read their text up to **There Are Substances in Soil.**

Why does a green plant need soil? What is in soil? Can a green plant live without soil?

Now encourage the children to design their own investigation (page 143).

Developing the Concept

Children gain an understanding of some of the steps in scientific investigation as they study how a green plant changes matter from the environment into more of itself.

Materials used by a green plant. As children read through van Helmont's experiment, be sure they follow his reasoning.

Where did he get his question? What was his hypothesis? How did he get his evidence? (By designing a controlled investigation.) Others during van Helmont's time believed something about plants without having *evidence;* that is, they really had not tested their beliefs. A hypothesis, children will recall, must be subjected to testing in order to prove (*confirm*) or disprove it.

The children follow van Helmont's reasoning: Why did van Helmont plant the willow in a tub of soil? Why couldn't he have simply observed the growth of a willow tree in the woods? Could he have accurately weighed the loss of soil for a plant growing in the ground? By putting the willow in a tub, what kind of investigation was he doing? (He was controlling the variables; that is, he was doing a *controlled* experiment.) Bring out the meaning of the term *control.*

When van Helmont took his measurements after five years, did he get the results expected? Did the soil lose as much weight as the willow tree gained? To help children compare the weight lost by the soil to the weight gained by the tree, let two or three children whose combined weight is about 164 pounds stand together. Hold up three envelopes with ordinary mail in them as a rough comparison.

What new hypothesis did van Helmont then develop (page 142)? Why was it only partly right (page 144)? As the textbook states, knowledge of how a green plant makes food was limited. We are still researching photosynthesis, of which some of the concepts will be explored in later sections. We now know that the change of matter into the substances of a green plant takes place in many, many steps. Some take place in the dark, others in light. The oxygen given off by the plant comes from water, not from the oxygen in carbon dioxide. The red light portion in a spectrum of sunlight is the most important in providing the energy. And there are many more details. Our present knowledge depends upon the concept of matter as being made of particles and the concept of energy changes taking place within an organism.

Minerals important for plant growth are found in soil water.

Minerals in soil water. Encourage performance of the additional investigation on page 143. Children repeat the original investigation but now use distilled water that has *not* been mixed with soil. When no residue appears in the beaker this time, they can draw a more certain inference that what was left over in the beaker before did indeed come from the soil. What kinds of substances are left behind? (Minerals.) This is the *control* and is always an essential part of a scientist's experiments.

Why did the water seem clear even though something was dissolved in it? Children may be able to draw from earlier experiences. A mineral substance that has dissolved in water has separated into tiny particles smaller than molecules. When the water evaporated, the particles came together again as crystals large enough for us to see. (For your own information, crystal structure of salts is different from molecular structure, but children are not ready for the concept and it is not needed at this time. A chemical formula for a substance is a ratio of the number of atoms that combine to form a new substance, a molecule, perhaps. But a formula does not necessarily mean a molecule, especially for a salt.)

Extending the Concept

Equipment and Materials

. . . various measuring tools, such as 12-inch ruler, yardstick, cloth tape measure

Planning investigations. Do the children have ideas about their own growth that they would like to investigate? For example: "I (or my hair, or my nails) grow about $\frac{1}{2}$ inch a month." Help them plan and carry out their investigations with such questions as: What measurements will they have to record? How can they make sure their measurements are accurate? Why is exact measurement important?

Water as a solvent. Encourage children to name substances they think will dissolve in water and others that will not. Then let them plan investigations to test their hypotheses.

Show them how to place some salt in a paper cone or cotton filter and pour water through it into a collecting jar. Let the collected water evaporate and then measure how much salt the water has picked up. How does this suggest that water running through soil picks up minerals?

If you live on the coast, boil or evaporate seawater, and measure the residue. How does the mineral content compare with that of fresh?

Investigating hard water. What is "hard water"? Hard water has a sizable amount of mineral salts dissolved in it. A peek into an old teakettle at home may reveal a coating formed by the minerals in hard water. Children can test tap water at home. Place a soap chip of the same size in two jars, one containing distilled water and the other an equal amount of tap water. Close the jars tightly and shake them equally. If there are fewer suds in the tap water, the tap water is probably hard.

Equipment and Materials

. . . paper cone filter or cotton filter (see page 143)
. . . tap water
. . . "seawater," natural or synthetic
. . . 2 equal-sized glass jars, with screw-on lids
. . . soap chips

Reviewing the Concept

(*Text pages 145–46*)

Before You Go On. 1. a 2. b 3. a

Using What You Know. 1. He planned a carefully controlled investigation to determine whether the commonly held idea was actually true. (See "Developing the Concept" above.) 2. The investigation (143) shows some of the laboratory evidence. 3. a; plants without chlorophyll cannot make food.

Section 3: AN APPLE TREE IS A FACTORY

(*Text pages 146–51*)

SUBCONCEPT

Using energy from light, green plants make their own foods from inorganic substances in the environment.

Children make further analyses of the way a green plant makes complex food from the simple substances it takes in. For these changes, the green plant must also have energy from light.

Introducing the Concept

Place a bottle of maple syrup on the desk. Why do we use syrup? How does it taste? Where does this sweet syrup come from? Trace it back to its original "factory," a sugar maple tree in Vermont, perhaps. Pictures of farmers tapping maple trees are available from state commerce and industry groups.

Where did the sugar in the tree come from? Was it in the soil, perhaps? Or in the water or air? No; it was made in the tree, by the tree itself.

What substances do green plants make?

After the children have discussed hypotheses, let them read the text up to **What Sugar Is Made Of** and prepare for the investigation on text page 147.

Equipment and Materials

. . . syrup
. . . picture of maple trees being tapped for sap

Developing the Concept

From investigation, children infer that sugar is a compound of carbon, oxygen, and hydrogen atoms.

The investigation. Children find that water and carbon are deposited as sugar burns. Many children may mistakenly believe that all substances when burned leave a black deposit. If so, they may not appreciate that

Processes emphasized

Development of models
Observation
Analysis of observations and models
Hypothesizing
Theorizing
Investigation (with design of experiment)

Equipment and Materials

See text page 147; also the Teacher's Manual for *Classroom Laboratory 4.*

the results indicate the presence of carbon. You may wish to say that only substances containing carbon will leave this black deposit when they are burned.

When heating the sugar, insist on the precautions cited: dry test tube, test tube directed away from all persons, test tube rotated to distribute the heat. Children will appreciate safety procedures better when presented as the procedures of scientists and not as cautions just for children.

From the investigation, children may be able to infer that the tree must have made the sugar from substances it took in which contained the elements carbon, oxygen, and hydrogen. Some children need to read text page 148 first. Can your body make sugar in the same way?

The total amount of sugars made on earth by green plants in one year has been estimated at 400,000,000,000 tons. As you write this figure on the board, children will realize the immensity of this amount. It may be made to seem much larger by asking: How many pound boxes of sugar are there in a ton?

From observed results, children infer that starch, like sugar, is a compound made of atoms of carbon, oxygen, and hydrogen.

Equipment and Materials

. . . starch or food rich in starch

What is starch made of? The additional investigation (page 147) may be postponed until after children have read through page 149. Children then can recognize that starch and sugar are made of the same kinds of atoms but in different proportions. The formula for starch is $C_6H_{10}O_5$. Powdered cornstarch, white bread, or soda crackers may be heated. Explain that bread and crackers are chiefly starch so that any substances obtained by heating them are probably from starch.

Through the use of models, children discover that different compounds have different numbers of atoms in their molecules.

Molecular models. To help children "read" diagrams, ask: "In the model of the sucrose molecule (page 148), which color stands for the atom of oxygen? of carbon? of hydrogen?" Discourage children from using color as a clue. Can we speak of such tiny, invisible bits of matter as having color? Instead, ask them to examine the formula for sucrose. How many atoms of oxygen does sucrose contain? (11.) How many atoms are colored red in the sucrose model? (11.) You can now infer that red stands for oxygen, and black stands for the 12 carbon atoms.

Children will be able to count only 19 of the 22 hydrogen atoms in the sucrose model. Why? Is it possible that some hydrogen atoms are hidden behind the others? Use this thought to point up the three-dimensional nature of atoms and molecules.

What is a model? Obviously, here the model is not the real thing. The model of a molecule is much too big. To scientists, a model is just a way of showing what they believe something looks like. It may be a drawing, a construction, or just a comparison in words.

Ball-and-stick models of molecules show us: the kinds of atoms in each molecule; the numbers of atoms of each kind; and, to some extent, where the atoms are "attached" to each other. Of course, the sticks are models too; they stand for the forces holding the atoms together.

However, ball-and-stick models of molecules do not show that molecules and atoms are always moving. Nor do they show that the atoms have different masses, the hydrogen atom being the smallest in mass.

Light energy needs of green plants. In investigating the light needs of green plants (page 150), it is important to remember that the needs of a seed are somewhat different from those of the plant that sprouts from it. The seed carries its own supply of food and is therefore independent of photosynthesis for a time. Encourage comparison of seedling growth after at least a week or two.

Children infer that the amount and kind of light energy received affects the ability of green plants to make food and to grow.

Equipment and Materials

See text page 150; also the Teacher's Manual for *Classroom Laboratory 4.*

Help children to distinguish between evidence they observe directly and inferences they draw from their observations. Perhaps one plant seems to be growing better than another. The inference may be that more sunlight results in better growth. Here an important question remains: Are you sure that the differences depended on the difference in light? Could any other condition account for this difference?

When an investigation "doesn't work," (doesn't give the expected results), encourage the children to evaluate their investigation. Perhaps your hypothesis was wrong. Perhaps you should change your hypothesis and try again. Perhaps your plan was wrong, or the materials, or the way conditions were set up. It is important for development of concepts and techniques of inquiry for children to recognize when to say, "I cannot decide anything definite from these results because . . ."

Be sure, as children plan the additional investigation (page 150), that they form a hypothesis as to what the results may be. Will different colors of light influence the plant growth? What color do you think will be best for the plants? The identical setup as before may be used, varying the light bulbs. Or a string of colored Christmas tree lights may be hung over boxes of plants, so that each box receives light of a different color.

To help children interpret their results, let them recall that sunlight may be broken into a rainbow (spectrum) of colors: red, orange, yellow, green, blue, indigo, violet. Their probable results will be that plants under red light will grow best and those under green light hardly at all. Green plants use chiefly the red and violet ends of the spectrum in photosynthesis and absorb the green light the least.

Extending the Concept

For what purpose does a plant use the food it makes? After discussion and hypothesizing, children can see for themselves one way in which plants use stored food. Have them measure with a tape measure the waistline of a large fat onion. Set the onion in the mouth of a bottle or vase so that its base just touches the water. Keep it in a dark closet until it sends up a shoot. Measure its waistline again. Why does the onion's waistline become thinner as the plant grows? The onion bulb is full of stored food which the shoot used as it grew.

Equipment and Materials

. . . onion bulb
. . . plastic bottle or vase
. . . scissors
. . . cloth tape measure

Fats as a product of plants. Children may find it difficult to think that plants make fats. On separate sheets of paper, spread sugar, starch, and chopped peanuts. Flatten each substance against the paper with a piece of cardboard, noting that only the peanuts leave an oily trace. A lighted lamp will make the oily spot even more visible. This is a useful test for

Equipment and Materials

. . . sugar
. . . starch
. . . peanuts
. . . lighted lamp

fats. Are peanuts the only plants which shift around the atoms in sugar to make fats? How do we get corn oil? Interested children may do research and draw pictures of green plants which produce nuts or other fat products.

(*Text page 151*)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. b

Using What You Know. 1. For one thing, the numbers of atoms of each kind are different. 2. From sugar. 3. a

(*Text pages 152–57*)

SUBCONCEPT

Matter from the environment is used for growth by cells of green plants and of all other living things.

Processes emphasized

Observation
Analysis of observations
Study of models (invention)
Library research
Recording
Reporting

Equipment and Materials

. . . tape measure

Section 4: A TREE GROWS

Children become aware that the cell is the building unit of the green plant, as of all other living things; that a plant grows by cell division; and that a plant has specialized cells for special functions.

Introducing the Concept

Call two children to the front of the class. Ask one child to measure how high the tip of the other child's nose is from the ground. Ask the child being measured to show, roughly, how tall he expects to be next year. Ask the class: Will the tip of his nose then be higher from the ground?

Children quickly realize that, if the distance between the nose and the ground does not change, their classmate would have to grow only in the distance between nose and top of head. What a huge forehead he would then have!

How does a tree grow? Does it grow bigger and taller by growing equally all over?

Children then read as far as **Inside a Tree** and plan the investigation on text page 153.

Developing the Concept

Children infer that different parts of a tree grow at different rates.

Investigation. As children read, ask for their hypotheses regarding the growth of a tree. They check these hypotheses by studying the pictures of the results of one investigation (page 153). Watching their own investigations over several weeks will be a source of interest to the class.

Living things are made of cells. They have a complex structure.

A typical plant cell. What is a plant cell like? Let children examine the illustrations of typical plant cells and plant cell division (page 155) *before* they examine the different types of plant cells (page 154). Such questions as—What do you see?—may guide close examination.

In examining cell division (page 155), offer only as much of the following as children seem ready for: All cells are made of a living substance (*protoplasm*) which is capable of making more of itself by using materials from its environment. The denser gray center (*nucleus*) is a special type of living substance which controls all of the activities of the cell, including cell division. Under the microscope, a dye affects the denser nucleus differently from the rest of the cell, thus making the nucleus readily visible.

The rest of the living substance (*cytoplasm*) is in light green. In plant cells, the cytoplasm may contain, as here: egg-shaped bodies (*chloroplasts*), shown in bright green, that carry the green matter (*chlorophyll*) of plant cells; cavities (*vacuoles*), in white, that fill with sap, water, and dissolved compounds.

Surrounding the cell is a thick *cell wall,* which is not protoplasm but nonliving *cellulose.* Lining the inside of the cell wall and so thin as to be almost invisible even under a microscope is the living *cell membrane.* The thickened cell walls of older plant cells are responsible for hardness of wood and the indigestible roughage in plant foods.

A typical animal cell is similar to the plant cell but has no cell wall or chloroplasts. Cells are of many shapes besides those pictured.

Living things grow by cell division.

How plant cells divide. "Reading" of diagrams of cell division is an excellent means of developing the concept. Between the time of the first and second pictures, what happened? (The dark center spot divided, making two parts of itself instead of one. The whole cell began pulling apart into two parts.)

By the third picture, what has happened to the cell wall? (New cell walls had grown in the middle, forming two complete, separate cells.)

Why are the cells in picture 3 bigger than the cells forming in picture 2? Children may infer that the new cells have grown. Point out that cells do not divide until they grow to a certain maximum size typical for them. Judging by their size, these cells are as mature as the cells in picture 1 and should start dividing any minute. How many cells will there then be? Call attention to the large number of cells made possible by the continuing processes of cell growth and cell division.

The structure of cells varies according to the functions of the cells in the organism.

Different kinds of plant cells. After several attempts at reading diagrams, children quickly discover (page 154) that different parts of a tree have different kinds of cells. They may find it helpful to study one row or column at a time, blocking out the others with a sheet of paper.

What is a leaf cell like? Children can see the single layers of protective cells on its top and on its bottom surfaces. Between these layers are the cells that carry the chlorophyll needed for food-making. The cells bunched into a circle represent a vein running across the leaf. The hole at the bottom surface of the leaf is one of the *stomata* through which air enters the leaf, moves into the large spaces between the loosely packed cells, and finally moves into the cells themselves. Gases leave the cells by the same route.

How does the trunk grow? The trunk grows in thickness by the dividing of only a single layer of cells, the *cambium,* that lies between the bark and the inner wood. As this single layer of cells divides, wood keeps forming on the inside and bark on the outside. The forming of the inner wood pushes the cambium layer constantly outward but not upward. This explains what has happened in the picture on page 156.

The cross-section of the trunk shows the "annual rings." Some children may know that you can tell the age of a tree by counting these rings. The cambium cells grow at a different rate at different seasons, and the annual rings show this difference. Where there are no definite seasons, trees show these rings less conspicuously or not at all.

How are root hair cells different? They have projections whose special work is to absorb water from the soil; the projections greatly increase the absorbing surfaces of the cells. Remind children that the delicate fuzz they have seen on the young roots of sprouting radish seeds are root hairs. Children may have noticed that nursery plants are sold with a protective covering around the roots. Why? The covering keeps the root hairs from drying out, which would damage their ability to absorb water.

Now, from which part of the tree did the cells shown on page 155 come? (Probably the leaf.) What do the leaf cells have in them that is not in the cells of trunk or root? (The green matter.) Can the trunk or root cells shown make food? (No. Only cells with green matter can make food.)

Extending the Concept

Equipment and Materials

- . . . plastic boxes
- . . . cork fragments
- . . . dry split pea halves
- . . . transparent food wrap

Building cell models. Encourage children to build or suggest models of cells. For example, how would you explain to someone who had never seen a cell what the cell on page 155 looks like? Would you say it looks like a sugar cube, a toy block, or . . . ? How would you show what is inside the cell? Let children use their imagination to design their own models.

Encourage children to explain their models, with others evaluating them in these terms: In what ways is the model like a cell? In what ways is it different? How can we improve the model?

A satisfactory model of a plant cell may be made using a small plastic container as the cell wall. Transparent food wrap can represent the cell membrane. Clear gelatin mixed with water can be the cytoplasm, a bit of cork the nucleus, and a few green split pea halves the chloroplasts.

Finding out more about tree growth. Children may try to find information on the following subjects by using books on the science reading table or in the library: the annual rings of a tree; the age of some of the oldest trees; the height and width of some of the largest trees. Are trees the biggest and oldest living things on Earth today? The class may plan and write a letter to a national or state park forestry service or to a large paper or lumber company to gather more information about trees. Children should report their source of information as well as their findings.

(Text pages 156–57)

Reviewing the Concept

Before You Go On. 1. a 2. a 3. b

Using What You Know. 1. The middle picture should be last. 2. Cells, because all living things are made of cells.

Section 5: A TREE FALLS

Children begin to realize that a tree, alive or dead, affects the environment of the other plants and animals around it.

Introducing the Concept

Hold up two cups of soil with the question: Which soil would you choose to plant a geranium in (or another flowering plant)? Why?

One soil sample should consist of sand and gravel, the other chiefly of humus. Children will tend to choose the rich, dark, humus soil. Why? Accept their reasoning without evaluation at this time.

What does rich soil have in it? How did the substances that make it rich get there?

Developing the Concept

After children have read the opening paragraph (text page 157), encourage hypotheses on how a living oak tree changes the environment of other plants and animals. What ways are mentioned? What other ways can you think of? Children may be able to add that, in making its food, the tree takes in carbon dioxide and gives off oxygen, the gas animals must breathe to stay alive. Trees, and all green plants, thus help keep the air in condition for all living things.

Investigation. When a tree dies, does it stop being useful? What happens to it? After initial responses, let the children read through and prepare to work on the investigation. Since it will take time to notice results, the text of the investigation should be discussed. What makes the mold grow? Does it make food? (No; it has no chloroplasts.) The mold gives off certain substances (*enzymes*) which change (*digest*) the bread, breaking it down into sugars which can enter the cells of the mold in dissolved form and be used for growth. What the bread mold does to bread in digesting it is much like what you do to bread in your mouth, stomach, and small intestine.

Nongreen plants cause decay. Children read **A Tree Starts to Disappear** (text page 158) and infer the similarity between the action of the mold on bread and the action of fungi on dead trees in a forest. Ask children to describe fungi they have seen and where they were growing. Were they getting much sunlight? What were they using as food?

Fungi obtain food by digesting and absorbing matter from other organisms, living or dead, or their products, such as grains, leathers, and so on. Although some fungi have color, such as the green mold that attacks fruit (pictured on page 158), this green pigment is not the chlorophyll necessary for photosynthesis, and fungi are considered "colorless" plants.

If the children made models of leaf cells for Section 4, how would these models have to be changed to represent fungi or bacteria cells? What is the important green matter not found in fungi or bacteria cells? (Chloro-

(Text pages 157–63)

SUBCONCEPT

Through the action of bacteria and other organisms, the matter of once-living things is returned to the environment.

Equipment and Materials

. . . soil rich in humus
. . . sandy soil with no humus

Processes emphasized

Observation
Analysis of observations
Investigation (with design of experiment)
Reading for data
Hypothesizing
Theorizing
Prediction

Children infer ways in which plants and animals may be interdependent. Nongreen plants are dependent on green plants or their products for food.

Equipment and Materials

See text page 159; also the Teacher's Manual for *Classroom Laboratory 4.*

Children relate the action of the mold on bread to the action of bacteria of decay on dead plant and animal cells.

phyll.) Interested children may do research on fungi or bacteria in the library and make cell models for comparison with those of leaf cells.

Children learn how nongreen plants are adapted for obtaining food and reproducing.

Structure of familar nongreen plants. What part of a mushroom do we eat? Do we eat the whole plant? Refer children to the bracket fungus on page 160 and let them note the threadlike parts growing into a tree. The mushroom has similar structures under the soil in which it grows. We eat only the reproductive part bearing the spores.

Equipment and Materials

... fresh, large mushroom
... bowl
... white paper
... hand lens

Get a fresh mushroom from the grocery and gently separate the cap from the stem. Place the cap, gill side down, on soft white paper. Cover this with an inverted bowl and let it stand for a day. Remove the cap carefully, and children should see the radial pattern made by the spores falling out of the gills. In the picture (page 158), children can see the gills, which carry the tiny tough-coated spores, on the underside of the mushroom cap. Each spore is a single cell which will grow into a new plant under favorable conditions.

The action of decay returns to the soil compounds essential to growing plants.

The decay of living things. Have children bring in and examine bits of decaying wood as they read **A Tree Decays** (page 161). What else can they add to the description of the decaying wood? Encourage them to observe minute details by passing around a piece of decaying wood and by asking, "What else do you see in the wood?" The observation may be simple, such as: "I see some reddish color here." Emphasize that when scientists examine the results of their experiments, they must observe keenly even the tiniest signs. These tiny signs may be clues to a new discovery.

Equipment and Materials

... decaying wood or humus
... hand lens
... paper towel or blotter
... jar with tight lid

Children may be able to recognize directly the presence of invisible organisms at work in decaying wood or in humus. Have the children spread some humus or crumbling wood on a wet paper towel or blotter; then have them place this in a warm, dark place, and observe it daily with a hand lens, if possible. In several days, bacteria and mold spores in the humus or wood may have multiplied to produce colonies big enough to be seen. A smooth red, yellow, or orange patch is probably a bacteria colony, while a black or blue-green fuzz is probably a mold.

Extending the Concept

Fertilizing the soil. The American Indian planted corn in little hills. Under each hill, he would put a few grains of corn and a dead fish. Why did he include the dead fish? What kinds of substances do growing corn plants need in the soil (text pages 142–43)? Children may reason that the body of the fish, as it decays, returns protein to the soil and, therefore, nitrogen and other elements needed by the corn plant.

Interested children may investigate, through reading, other ways in which soil has been fertilized through the ages, such as: compost piles; manure; plowing the stalks of farm crops into the ground; growing grasses and clover and plowing them under as so-called "green manure;" and the present-day use of commercial fertilizers. Their findings may be exhibited in large, labeled drawings.

How else does humus improve the soil? The outlets of three large funnels of the same size should be wrapped with equal layers of cheesecloth. Partly fill one funnel with sand, the second with clay, the third with loam (soil which contains clay, sand, and humus). Fill each funnel to the same depth. Pour equal amounts of water through each funnel and collect in a container beneath. Which soil holds back the most water?

How can we interpret the results? Sandy soil allows water to evaporate or to pass through too quickly. Clay soil will tend to keep water from reaching the roots. Loam holds water, permits most plants to root well and thus to absorb sufficient water, and provides plants with minerals from the decayed matter in it.

Equipment and Materials

- . . . three funnels of same size
- . . . cheesecloth
- . . . sand
- . . . clay
- . . . humus
- . . . containers

Reviewing the Concept

(*Text pages 162–63*)

Before You Go On. 1. a 2. a 3. a

Using What You Know. 1. A fungus plant has no chlorophyll and, therefore, cannot make its own food. 2. They break down the bodies of dead plants and animals, so that enriching substances are returned to the soil. 3. a; decaying plants return to the soil the substances they took from it, enabling other plants to grow.

Section 6: THREE SEEDLINGS

(*Text pages 163–68*)

SUBCONCEPT

A living thing is dependent on all the conditions and all other living things in its environment.

The importance of interdependence of living things and their environment is reinforced as children continue to examine the adaptations of plants and animals to different environments.

Introducing the Concept

Prepare, in advance, pictures of animals and trees growing within their natural environments. You may wish to have volunteers help you trace the plant or animal outlines by holding the pictures against a windowpane. When these outlines have been cut out carefully, discard the shapes of the featured animals or plants and retain the background cutouts.

To introduce this section, hold up each picture of the plant or animal with the environment masked by the cutout. Allow the children (caution the volunteers not to give the show away) to describe what they think the environment of the animal is like. At a signal from you, the volunteers may participate, describing or naming the other plants and animals in the background.

Remove the masking sheet. What clues to the plant's needs or the animal's way of life does the picture of the environment now give you that you did not have before? What surrounding animals or plants help to keep it alive?

Is the swamp oak tree we have been reading about dependent on other living things in its environment? Let's find out.

Processes emphasized

Observation
Model-making
Analysis of observations
Field trip
Hypothesizing
Theorizing
Prediction

Equipment and Materials

- . . . pictures of plants and animals in their habitats
- . . . scissors
- . . . white paper

Children discover ways in which a green plant may be dependent upon animals in its environment.

Different plants are adapted to different environments.

A difference in environment affects the kinds of living things that are adapted to a region of the Earth's surface.

Equipment and Materials

- . . . paper
- . . . drawing supplies
- . . . cellophane tape or paste
- . . . scissors
- . . . reference books

Most animals are adapted to living chiefly in a land, water, or air environment.

By using his brain to modify the environment, man is able to live in environments to which he is not structurally adapted.

Developing the Concept

How the oak tree needs the squirrel. The first two paragraphs reveal one way in which the oak tree is dependent upon other living things. Children may offer others, such as the oak tree's need, in food-making, for the carbon dioxide that animals give off or its need for the nitrogen compounds that enter the soil through the decay of dead plants and animals.

Can anyone think of ways that we may have played a role like the squirrel's? How about burs that cling to clothing? In what other ways are seeds spread?

Will the oak tree grow where the sumac will? Once the seed has been buried in the ground by the squirrel, will the seed grow? We have completed the life cycle of a tree here, returning to the question with which the unit began: Is it really easy for a seed to grow (page 137)? Children can discuss some of the conditions of the environment that will need to be just right for the oak seedling, in contrast to another kind of seedling.

Environments along a mountainside. An idea that may prove at first surprising to children but interesting to explore is that quite different plants and animals may be found at different heights of the same mountain. Why? How may the soil differ? rainfall? temperature? winds? Model a mountain by making a paper cone or by drawing a triangle. With the aid of library reading, children can insert labels or pictures of the living things growing at each altitude: perhaps snow only at its peak; stunted trees and lichens near the top; farther down, hardy evergreens and the insects and other animal life that survive with them; and so on. Then they should relate the zones of changing life to the changing vertical environment.

Living in water, on land, in air. In **The Importance of Environment** (text page 164) children begin to recognize that animals, too, are adapted to certain environments. The concepts introduced, including how a fish obtains oxygen from water, are fully developed in the next unit. You may therefore wish to confine the discussion to adaptation to the three types of earth environment—water, land, and air. For instance: a fish can move back and forth in the water and downwards quite a bit (as long as it finds food and the water pressure to which it is adapted), but can it move upward into the air to live? How about a bird? Can a bird move downward to live in water as a fish does? How about man? Have you ever tried to keep your head under the water during a swimming lesson? Are you well-adapted for living in water? Are you well-adapted for living at the top of the mountain or upwards beyond that?

Man adapts to many environments. Let us turn to the picture of the divers (page 166). How is man able to move under the water or out in space, even though he is not structurally adapted to these environments? You have been adapting to different grades in school. What part of your body have you used to do this? (Brain.) Because of his brain, man is able to invent ways to help him live in environments for which he is not specifically adapted. He often carries the environment he needs with him wherever he goes! Which part of their environment are the divers carrying with them as they travel under water? (Oxygen.) Where else besides under water does man have to carry the oxygen he needs? (Out in space.) How is a diver's suit a little like a space suit?

Can the children think of ways in which their ability to reason has helped them to adapt, to do things that their bodies alone could not have done? Have you been able to reach places you could not reach with your arms alone? Or lift things that were too heavy for you?

Ecology is the study of the relationship of living things to each other and to their nonliving environment.

As children read **An Environment for a White Oak Tree** (text page 166) you may wish to clarify the term *ecology*. It combines two Greek terms meaning "home" and "the science of," or "study of." Children will appreciate that the habitat, or specific environment of an organism, is indeed its home and that, like the homes of the children themselves, the habitat must provide for all the needs of the growing organism, if that organism is to survive. With what necessities do the children's homes provide them?

Extending the Concept

Equipment and Materials
. . . thermometers

Comparing environments. How many different kinds of environments for living things can children see just from their classroom window or, perhaps, from the school rooftop? Environments only several feet or even a few inches away from each other may be drastically different; the cracks on sidewalk pavements present an environment for living things which is quite different from the concrete itself or the soil next to it.

Children can find, by direct checking, that every factor can vary considerably. For example, how does the temperature near the floor of a room and near the ceiling of the same room differ? under the eaves of a house? on a sunny and a shady wall of the same house?

Knowledge of concepts, whether obtained by trial and error or by investigation, has been essential to keeping man alive.

Recognizing man's need for concepts. Why did the early colonists in New England find it difficult to survive? It was not so much because of the cold or other hardships but chiefly because of the lack of food. The colonists almost starved because they did not understand a concept that every child completing this unit knows: A plant is adapted to a particular environment.

The colonists had brought with them and planted European wheat as food. But the European wheat was not adapted to the new environment and could not survive. Without gifts of corn from the Indians and lessons in how to plant it the colonists would probably all have died of starvation.

Reviewing the Concept

(*Text page 168*)

Before You Go On. **1.** a **2.** b **3.** b

Using What You Know. **1.** (Children's choice.) **2.** Warm-bloodedness, lungs, legs, etc.

Section 7: THE MAIN CONCEPT: A LIVING THING IN ITS ENVIRONMENT

(*Text pages 168–73*)

CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

UNIT CONCEPT

Living things capture matter from the environment and return it to the environment.

Children tie together concepts they have gained from their investigations and study during the unit and see more clearly the interrelationships between living things and their environment.

CONCEPT SUMMARY

Can plants and animals live anywhere?

Equipment and Materials

- . . . park or garden in which planting is permitted
- . . . spade

Adaptation. Children will express this concept in their own words in answering speculative questions such as: What would happen to the animals in the local zoo if they were released into neighboring woods? Which animals would probably survive? Which would die? Why? Children may be able to find out the kinds of animals actually housed at the local zoo and their origin and, through library research, may be able to compare the natural environments of the animals with conditions found locally.

Children can speculate similarly on the fate of exotic plants being raised at a greenhouse. What would happen to these plants if they were planted outdoors under local conditions?

The class may get permission to spade out a block of soil about a foot square growing under a nearby shrub and another block in an open grassland. Each block should be removed deeply enough to have soil clinging to the roots. Interchange the blocks of soil, setting each flush with the soil and marking off each area. Water each area after transplanting but not thereafter. Have children compare the blocks frequently for several weeks to decide what kinds of plants seem adapted to or not adapted to their new environment. In their discussion of the results, children will be expressing in their own words the major concepts of the unit.

Can plants and animals live without each other?

Equipment and Materials

- . . . brown wrapping paper
- . . . white paper
- . . . paints
- . . . clay
- . . . cardboard

Interdependence. Children may prepare a diorama telling the story of the white oak described in their textbook. They may draw, model in clay, or find pictures of a white oak, a hawk, a green snake, chipmunks, fungi, and other interdependent plant and animal life mentioned in this unit. They will need to do library research on the homes of the animals, the kind of food they eat, and some of their adaptations. A forest painted on a large piece of brown wrapping paper may be used as a backdrop. A nearby chart can tell, in the words of students, of the growth of the acorn into a tree and then of the tree's death and decay. Each stage should show the tree's relationship to other living things and to nonliving matter in its environment.

Children can observe that a living tree or dead tree trunk is a community of many living things by keeping a day-to-day record of its short- and long-term residents. Children may be able to tell which animals have been there in their absence by observing tracks and other signs.

Sawdust around a tree suggests that some feathered animal (such as a woodpecker) or a six-legged one (some insect) has been at work. Can children follow the trail of sawdust to find the animals responsible? Once a tree is injured, fungi invade it readily, and fungi are probably the leading residents of a very old, damaged tree.

Can we group living things according to similar ways in which they are adapted?

Grouping living things. The varied environments to which plants and animals have adapted has helped produce a great diversity among living things. Children may be ready to classify plants mentioned in the unit into several main groups—bacteria, fungi, mosses, ferns, seed plants—according to their adaptations. The children should write a general idea of how the plants in each group are constructed, how they get their food, and the kind of environment which they require. Encourage library reading, and the making of booklets or other exhibits.

How is man able to live in a space environment for long periods?

Using the concepts to design a spaceship community. Help children to consolidate the main concepts by suggesting they design a spaceship in which man can live indefinitely. They have seen that on Earth plants and animals are interdependent, constantly using and reusing materials from each other. The balanced aquarium and the miniature world of living things in a test tube are tiny models of the concept. On a long space trip, how could we have enough oxygen, food, and water? Imagine the huge amounts that would have to be packed!

Instead of food, what might we take with us? (Green plants.) A tiny food-maker such as the green alga might do. (Algae are a group of single-celled plants not mentioned in this unit. Interested children may be encouraged to investigate them.) The algae could use light from the Sun for energy to make food.

Each day we will be giving off carbon dioxide about equal to the oxygen we take in. If carbon dioxide builds up in the capsule, what will happen? (The same thing will happen that happened to Priestley's mouse—Unit Four, page 123.) How can the carbon dioxide be removed? The algae will use it up in food-making, and in giving off oxygen. Decay bacteria and fungi will be needed to change wastes into mineral substances that the algae can use to make proteins. What will *we* use as food? The algae, perhaps. If the problem of cooking could be solved, we might take fish with us.

The algae will be food for the fish, the fish will be food for man, bacteria and fungi will convert wastes to food for the algae, the algae will be food for the fish . . . and so on, in a self-supporting food chain.

Of course, there are many other problems to be solved, but we are concerned here with the interdependence of living things and their environment.

After some discussion, ask children to design a space capsule for a long trip—to Mars, perhaps.

FIXING THE MAIN CONCEPTS

(Text pages 170–73)

Testing Yourself. **1.** a **2.** a **3.** b **4.** a **5.** b **6.** a **7.** a **8.** a **9.** b **10.** a

UNIT FIVE

THE FALL OF A TREE

The farmer was talking about his trees. "There was one tree I liked best of all," he said. "It was a huge white oak. It must have been at least two hundred years old. A hawk liked to perch high on a top branch, to look around. That white oak towered above the other trees.

"One day lightning struck the tree, perhaps because it was the tallest of all, and killed it. But it stood for four years. Then it fell and lay there in the woods.

"Now, some people might have thought that that tree's work was done. But it wasn't. A green snake raised its family under that tree trunk. So did some chipmunks. In fact, quite a lot of living things made their homes in it. Ferns and mosses grew around it and on it. That tree began to become part of the woods again."

How can a dead tree become part of the woods again? Let us explore life in the woods, and the life of a tree.

AN INVESTIGATION into Where Green Plants Will Grow

■

●

Needed: fifteen or twenty zinnia, or bean, or radish, or squash seeds; eleven paper cups, two saucers, cotton, a little vinegar, soil, sand

First make sure that the seeds are alive. Soak all the seeds in water, then place them on wet cotton in a saucer.■ Cover them with the other saucer. When a root begins to poke out of a seed, you will know that the seed is alive.●

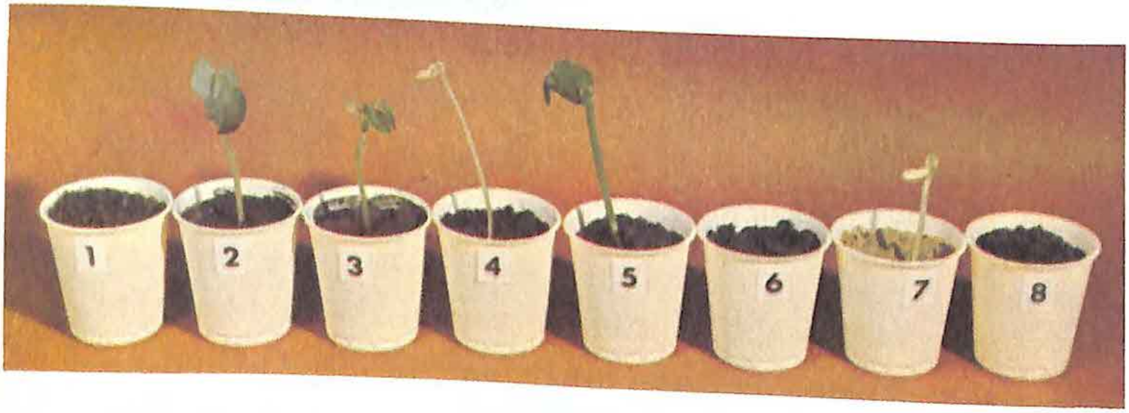
Number the paper cups from 1 to 11. Plant one live seed in each cup, as in the table opposite. (Use your imagination for planting of seeds for cups 9, 10, and 11.) Put each seed about one-half inch below the surface. Be sure to put each seed in the cup in the same way.

Notice that each seed is planted in different conditions. You may want to try still other conditions.

Do not mark this book. Record the results in your notebook.

On the opposite page are the results of one trial.▲ Under what conditions did the plants grow best? How do you know? Under what conditions was the growth poorest? How do you know?

▲



Cup number	Growing conditions till the seedling grows 2 inches	How it grew
1	In good soil, in good light, and watered every day.	
2	In good soil, in good light, and watered every other day.	
3	In good soil, in good light, and watered every fifth day.	
4	In good soil, in a dark closet, and watered every other day.	
5	In good soil, in shade, and watered every day.	
6	In good soil, in good light, watered every day —but with a teaspoonful of vinegar added to the soil.	
7	In sand, in good light, and watered every day.	
8	In good soil, in good light, but with cup standing in a pot of water. Make small holes in bottom of the cup with a pencil point, to let water in.	
9	Do this one your way.	
10	Do this one your way.	
11	Do this one your way.	

1. We Grow a Plant

Most people think it is easy to grow a tree. After all, all you have to do is get the seed of a tree and plant it. The seed grows, and in time you have a tree.

Is it really easy for a seed to grow? The answer might surprise you. Find out for yourself. Try the investigation on these two pages.

Where Will a Green Plant Grow?

Some of the seeds in the investigation did not grow. A seed will not grow just anywhere. Many, many investigations and experiments have proved it. A seed has to have certain conditions around it to grow. That is, a seed has to have a certain **environment** (en·VY·ron·ment). No two seeds had the same growing conditions. The kind of soil, the number of times the seeds were watered, and the amount of light were all part of the environment of each seed. You may have thought of another condition, too.

The eleven seeds in the investigation were in eleven different environments, then. You probably had little trouble deciding which environment was bad and which was good for the growth of the seeds.

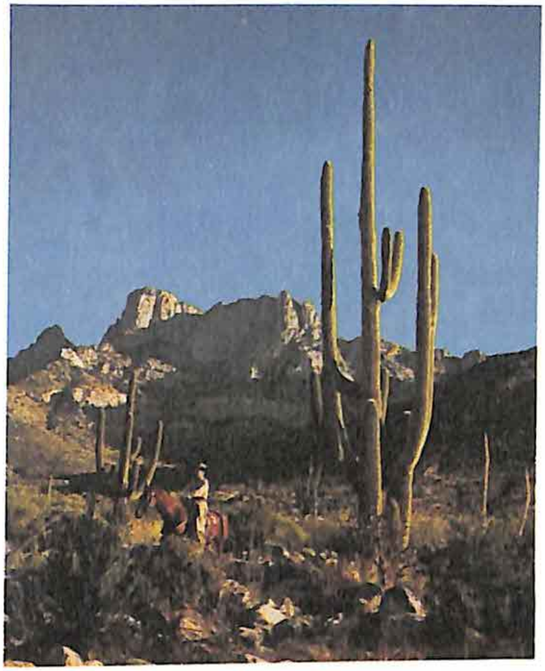
Now look at these plants. ■ What do you think is lacking in their environments? Water is lacking.

Plants grow best in the right environment, that is clear. But there is more to it than that. There are many different kinds of plants. Different kinds of plants need different environments. The best environment for one kind of plant can be a poor environment for another kind of plant. An environment in which a water plant can grow well is not good for a land plant. The desert is the right environment for this cactus plant. ● The desert is not the right environment for a maple tree or for a jack-in-the-pulpit. ▲

Most green plants living on land must have soil, water, light, and heat as part of their environment. But that is not enough. A plant must have the *right kind* of soil. Some plants, such as sugar beets, grow well in sandy soil where other plants cannot grow.

A plant must have the right amount of light. Some plants grow

■



●

▲

well in the sunlight; some, such as violets, grow well in shade. A plant must have the right amount of water. If too much water reaches a plant, the plant may actually drown. If there is too little water, a plant may not grow properly.

There are other things too that a plant must have, as you will see later on. But we can say all this in a single sentence. A plant must have the right environment to grow.

It isn't so easy to grow a tree after all, is it?

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept.

1. Plants
   a. can grow without water
   b. must have water to grow
2. Plants grow best in
   a. the right environment
   b. any environment

USING WHAT YOU KNOW

1. A cactus plant and a maple tree are both green plants. Both need soil, water, light, and heat in their environments. However, a cactus cannot live where a maple lives. How do their environments differ?

2. What do *you* have to have in *your* environment?

ON YOUR OWN

A boy planted ten bean seeds in good soil, putting each seed one inch below the surface. Each seed got the same amount of water and sunlight. Seven of the ten seeds poked their way through the soil. Three seeds did not. What went wrong?

■

2. The Scientist and the Willow Tree

In the year 1605 a Belgian scientist named Jan van Helmont took a willow branch and planted it. He did not plant it in the ground, however. He planted the branch in a tub of soil, with a lid on it. ■ For the next 5 years, Jan van Helmont watered that willow carefully.

What was he looking for? He wanted to know where the willow was getting the food substances that made it grow. The willow kept getting bigger. It had to be getting these substances from somewhere. Where was it getting them?

In a way this was a foolish question. Most people thought they knew the answer already. The answer was that the willow plant took substances *from the soil* to grow. Of course, every one had known that for a thousand years!

However, van Helmont was a scientist. He wanted evidence. So he set up an investigation. Suppose the willow did take substances from the soil as it grew. Then, as the willow grew and weighed more, the soil ought to weigh less.

Van Helmont weighed the willow branch before planting it. It weighed 5 pounds. He weighed the dry soil. It weighed 200 pounds. Then he planted the branch and watered it with rainwater for 5 years.

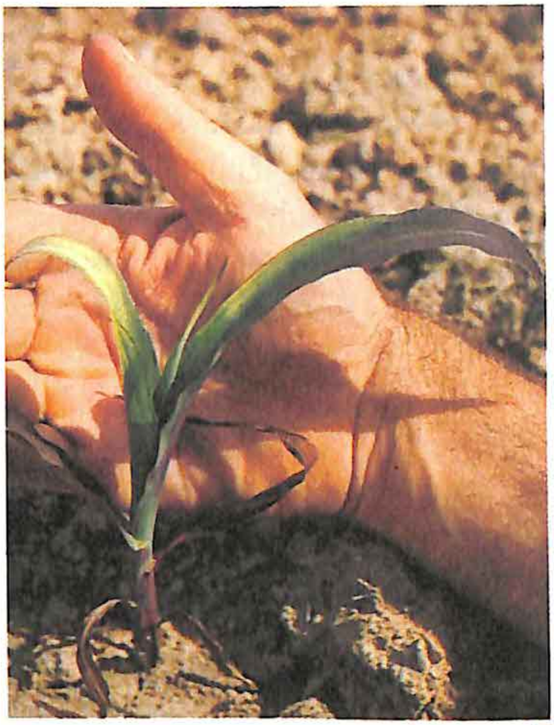
At the end of 5 years, the willow branch had become a willow tree, and it weighed 169 pounds. ● It had gained 164 pounds in weight. If people were right, the willow had taken 164 pounds of substances from the soil in the tub. Van Helmont took the willow tree out of the tub. Then he dried the soil in the tub and weighed it.

The soil weighed almost the same as it had when he first put the willow in it. It had lost only 3 ounces in weight!

This was an astonishing result. Where *did* the willow get the substances for its growth, then? Van Helmont thought of an answer, based on his experiment. What answer would you make? After you have thought it over, check your answer against van Helmont's, at the bottom of the next page.

Jan van Helmont was right, so far as he went. However, there was more to learn. Today, more than 350 years later, we know more about

■



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that willow tree—after many investigations. Are there substances in soil that a plant might take? Try the investigation on the opposite page for yourself.

There Are Substances in Soil

As the investigation shows, there are substances in soil. Do plants use these substances? Yes. Water dissolves these substances. Then green plants like the willow take up the water, and the substances in it, through their roots.

Here are two fields. One field is rich in the substances plants take from the soil. ■ The other is poor in these substances. Can you tell which field is which?

Green plants take from soil two kinds of substances. One kind is called **nitrates** (NY·trayts). These are compounds of nitrogen and oxygen. The other kind is called **phosphates** (FOS-fayts), compounds of phosphorus and oxygen. The corn plants in the second field will need an amount of nitrates for good growth. ● And they will need

---

Jan van Helmont concluded that the willow must have gotten its substances from the rainwater he gave it.

AN INVESTIGATION into Some Substances in Soil

Needed: a jar of garden soil, half a jar of distilled water, a wad of cotton, a funnel, a beaker

Distilled water is pure water: it has no substances dissolved in it. (You can obtain distilled water from a pharmacy.) Pour the distilled water into the garden soil and shake it. Let the mixture of soil and water stand overnight. If there are substances in the soil that can dissolve in the water, this will give them time to do so.

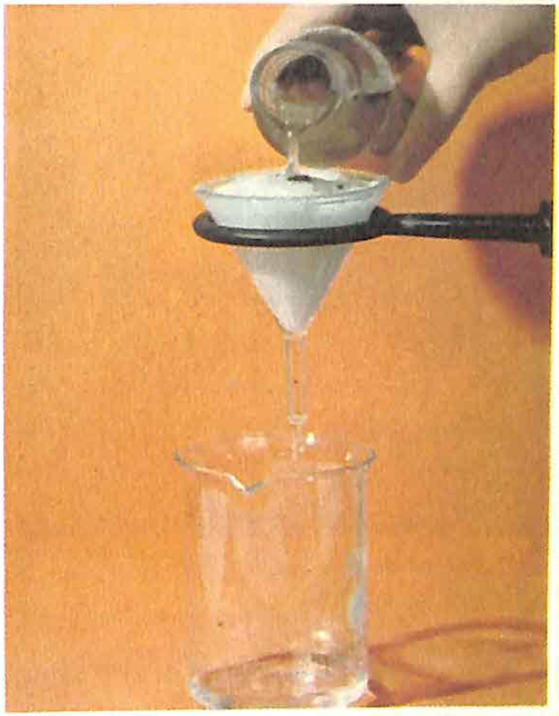
Pack cotton into the funnel. This makes a filter. Pour the water from the jar through this filter, to strain out the soil. ■ Only the water, and any substances dissolved in it, go through the cotton filter into the beaker.

Now evaporate the water in the beaker by letting it stand in a warm place or by heating the water gently on a hot plate.

Here are the results of one trial. Is anything left in the beaker? Where did it come from? ●

Did the soil contain substances that could dissolve in water?

Additional Investigation: How could you show that the distilled water you used in the investigation above has no dissolved substance in it?



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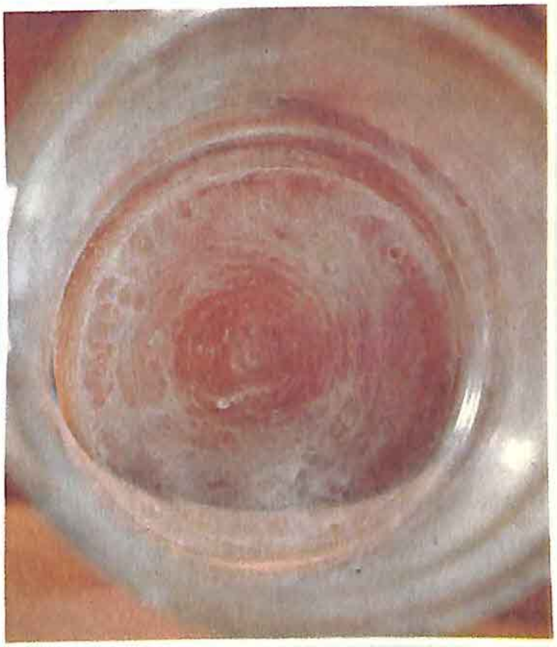

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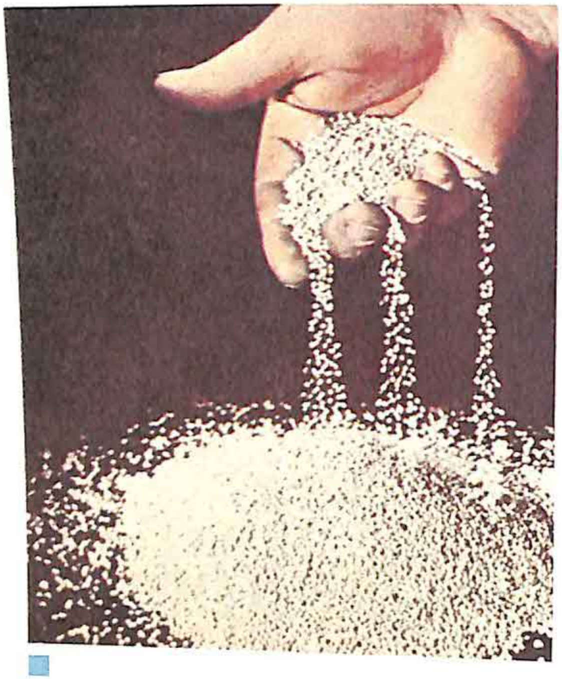

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a quantity of phosphates at the same time. However, wheat plants need different amounts of nitrates and phosphates than do corn plants. ■ Different kinds of plants may use different amounts of these and other substances in the soil.

Green plants take substances from the soil as they grow. These substances must be put back into the soil. If they are not, what you see in the second picture on page 142 happens. **Fertilizers** are substances that we add to soil to make up for the substances taken from it by plants. This fertilizer contains mainly nitrates and phosphates.

There are substances in the soil that plants use. Then why didn't Jan van Helmont find that the soil in which his willow grew lost a lot of weight? The answer is that the willow used only a very small amount of these substances, compared to the weight of the soil. Out of 200 pounds of soil, the willow used only about 3 ounces of substances in 5 years.

From Soil, Water, and Air

In 5 years that willow gained 164 pounds of substances. It got only a very little of them from the soil in the tub. Where did it get all the rest? Was van Helmont right? Did the plant get the rest from the water?

Jan van Helmont was partly right. The willow did get substances that were dissolved in the water. The willow also used the water. That was not the whole answer, however, for the willow got substances from another place as well. Today, after many investigations, after the work of many men, we know more about the substances green plants use.

A green plant uses substances that it takes from the air. It takes from the air a gas that has no color and no odor, called carbon dioxide. *A green plant can take carbon dioxide* *and water and use these to make other substances like sugars, starches, and wood fibers.*

This is one of the most important discoveries ever made by scientists. Van Helmont's willow made most of the substances in it out of carbon dioxide and water.

Green plants can make foods such as sugars and starches from carbon dioxide and water. However, green plants can do this only under certain conditions.

You probably know some of these conditions. Will a green plant grow if the weather is very cold? No. A green plant needs heat. Will a green plant grow in the dark? No. A green plant needs light.

With heat and light, a green plant can make food from substances dissolved in water and from carbon dioxide in the air. Colorless plants, such as mushrooms, cannot do what green plants do. They cannot make their own food.

Where does a green plant get these substances? From the Earth, of course. The Earth (and the air around it) is the great storehouse of soil and water and air for green plants. Where does a green plant get heat and light, though? The heat and light that green plants need travel 93 million miles through space—from the Sun.

Green plants use both the Earth and the Sun.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. To make food, green plants need the substances water and
   a. carbon dioxide b. light
2. To make food, green plants need water and
   a. darkness b. light
3. For the plant to use them, the substances in soil must be
   a. dissolved b. solid

USING WHAT YOU KNOW

1. Van Helmont was a scientist. Because he was a scientist, what did he do?

2. What evidence shows that there are dissolved substances in soil water?

3. Which of these statements is accurate? Why?
   a. Green plants can make food from carbon dioxide and water.
   b. All plants can make food from carbon dioxide and water.

ON YOUR OWN

You know more now about how plants grow than van Helmont did. Why is this so?

3. An Apple Tree Is a Factory

You know what this is, of course. ■ Did you know that it is made mainly of sugar? An apple has a good deal of sugar in it. That is one of the several reasons we like to eat it.

Yet an apple tree does not take in sugar. An apple tree takes in substances from the soil water and from the air. None of these substances is sugar. Yet an apple has sugar in it. Somehow, an apple tree makes sugar.

Isn't this remarkable, when you think of it? You certainly could not tell by looking at an apple tree that it is doing such a thing. Let us find out what is going on here.

A good place to begin is with this question: What is sugar made of? The investigation on the opposite page will help you find out.

AN INVESTIGATION into What Sugar Is Made Of

Needed: sugar, a test tube holder, a Pyrex test tube, an alcohol lamp or a Bunsen burner

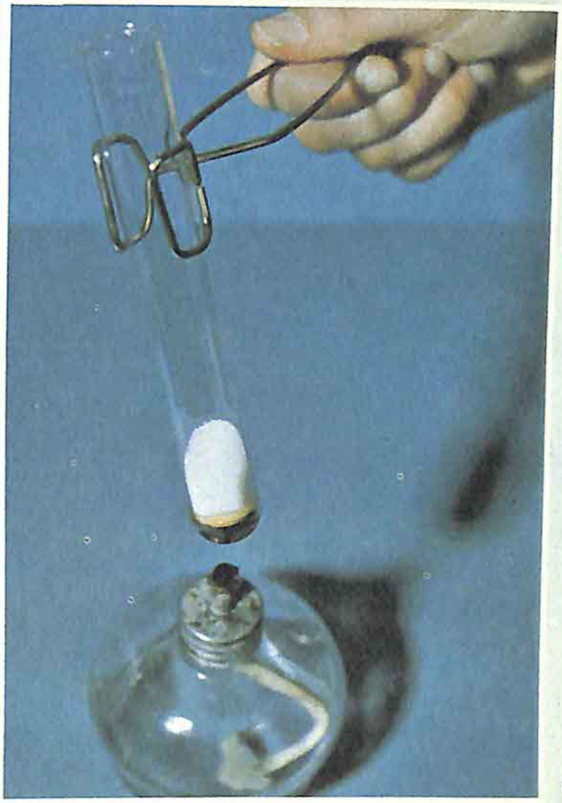
Make sure that the Pyrex test tube is dry. Then place about a quarter of an inch of sugar in it. Put the tube in the test tube holder.

Heat the sugar gently, holding the tube as shown. ■ *Remember that a tube being heated should never be pointed toward anyone!* Be sure to move the tube around so that every part of the sugar is heated equally. As the sugar gets darker, some vapor will be given off. Heat the tube until the sugar is black. Here is what happened in one trial. ●

What do you observe on the side of the tube? What is it?

What is the black substance at the bottom of the tube?

Additional Investigation: Sugar and starch are made of the same substances, but the amounts are different. Show that at least one substance found in sugar is also found in starch.



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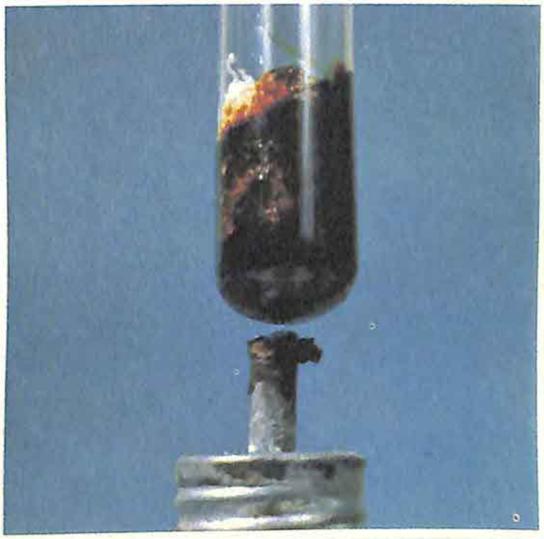

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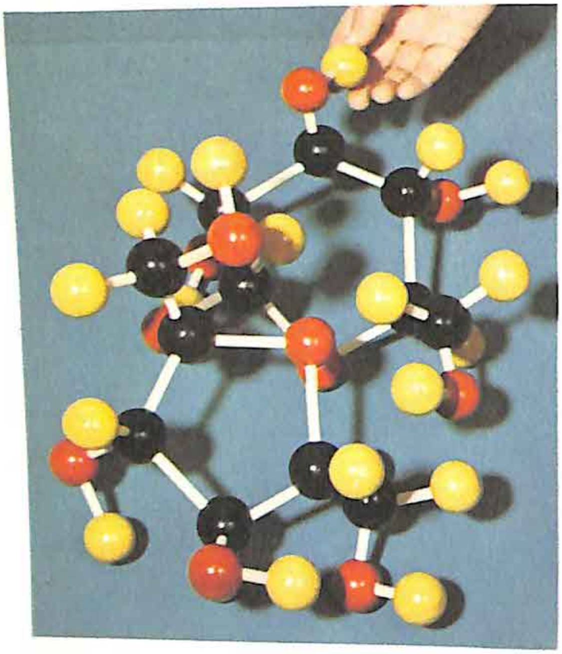

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What Sugar Is Made Of

When sugar is heated enough, a black substance appears. This black substance is carbon. There is carbon in sugar.

What about the drops that appear when sugar is heated? They are drops of water. Water, you know, is made up of hydrogen and oxygen. So there are hydrogen and oxygen in sugar, as well as carbon.

There are different kinds of sugar, but they are all made up of atoms of carbon, hydrogen, and oxygen. The table sugar used in the investigation is a kind of sugar called *sucrose* (SUE·krohs). (Try saying "Please pass the sucrose" next time.)

A molecule of sucrose is made up of 12 atoms of carbon, 22 atoms of hydrogen, and 11 atoms of oxygen. A model of a molecule of sucrose looks like this.■

There is a shorter way of saying what is in a molecule of sucrose. A chemist simply writes $\mathbf{C}_{12}\mathbf{H}_{22}\mathbf{O}_{11}$. **C** stands for carbon, **H** stands for hydrogen, and **O** for oxygen. The numbers stand for the number of atoms of each in the sucrose molecule. (Instead of asking for the sucrose, you could say, "Please pass the C twelve H twenty-two O eleven.") $\mathbf{C}_{12}\mathbf{H}_{22}\mathbf{O}_{11}$ is the formula for sucrose.

Another kind of sugar is called *glucose* (GLUE·kohs). An apple makes glucose. The formula for glucose is $\mathbf{C}_{6}\mathbf{H}_{12}\mathbf{O}_{6}$. Can you tell from this formula how many atoms of carbon, hydrogen, and oxygen there are in glucose? You can check your answer by counting atoms in this model of a glucose molecule.●

The Food Factory

Most green plants make the kind of sugar called glucose, to begin with. Then, having made glucose, the plants change it into other kinds of sugar. For instance, a sugar cane plant first makes glucose. Then it changes the glucose into sucrose, from which table sugar comes. Fruits like apples and oranges are storage places of sugar.

In many plants the sugar is changed to *starch*. Some plants store the starch. A potato is made of starch stored by the potato plant. Some plants, such as the cactus and rhubarb, store starch in their stems. Sugars and starches are **carbohydrates,** compounds of carbon, hydrogen, and oxygen.

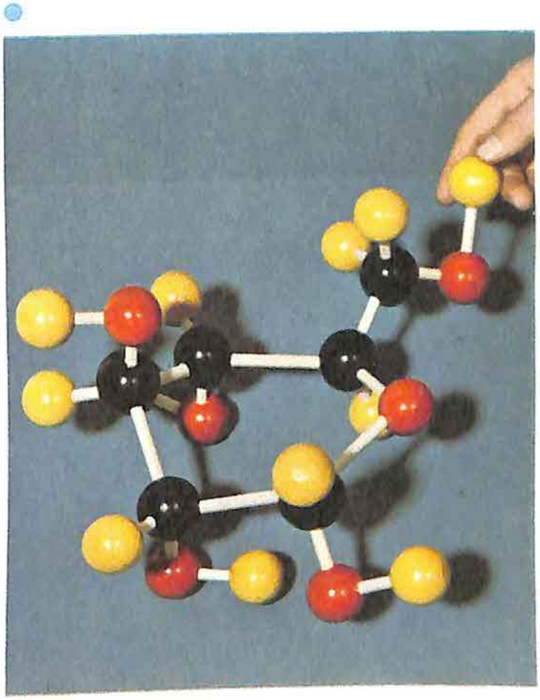
The sugars that plants make can be changed in other ways, too. Sugars can be changed into **fats.** Fats are made up of carbon, hydrogen, and oxygen atoms, as sugars are. But the number of atoms and the way they are combined is different. The green plant shifts the atoms around to make fats out of sugars.

Plants can add other substances to the sugars they make. A plant may start with sugar, for instance, to make a substance we call **protein.** To make protein, atoms of nitrogen are combined with carbon, hydrogen, and oxygen. Like sugars and starches and fats, protein is also an important substance.

Why are sugars and starches and fats and proteins important? Perhaps you already know the answer. Sugars, starches, fats, and proteins are *foods*. You do not have to be told how important foods are. Remember that foods are not only necessary to you. Foods are necessary to every living thing.

The green plant is a kind of food factory, in a way. The green plant makes sugars, starches, fats, and proteins. The green plant is also a storage place for these foods that animals must eat.

The green plant must have energy to make sugars, starches, fats, and proteins. Where does the energy come from? Try the investigation on the next page and see for yourself.



AN INVESTIGATION into Energy for a Green Plant

Needed: twelve radish seeds, three small jars, blotting paper

Line the jars with blotting paper. Label the jars 1, 2, and 3. Put four radish seeds around the side of each jar, between the glass and the blotting paper. Wet the blotting paper. ■

Put jar 1 in a dark closet or drawer where it can get no light. ● Put jar 2 where it will get light only from an electric lamp. ▲ Put jar 3 where it will get some sunlight from time to time. ◆ Do not forget to keep the blotters damp.

Observe how the seeds grow. Is light necessary? Is sunlight necessary? Here is what happened in one trial. ★

Additional Investigation: Does a red lamp make a difference?

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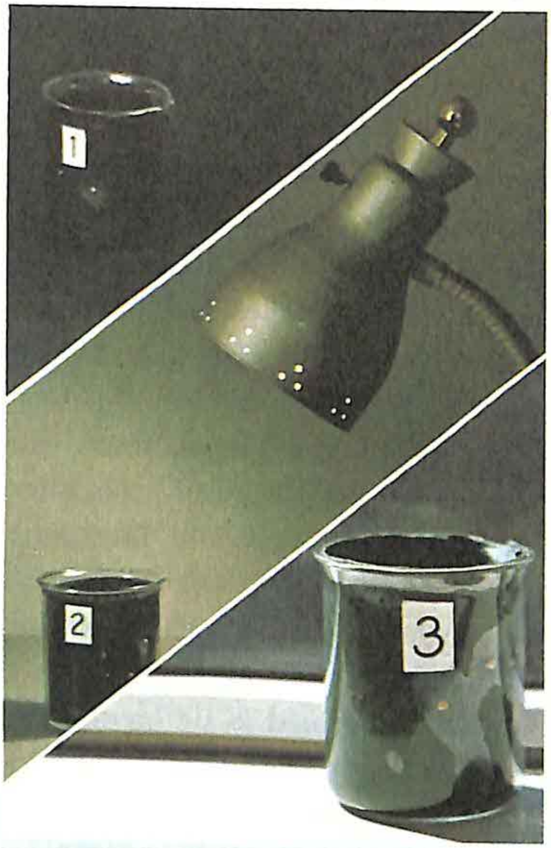

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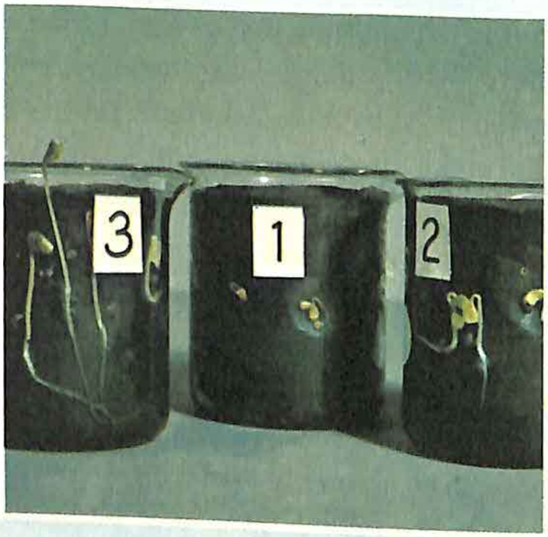

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BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Glucose, sucrose, and starch are made up of carbon, hydrogen, and
   - a. nitrogen
   - b. oxygen

2. Proteins are different from starches because they contain
   - a. nitrogen
   - b. oxygen

3. Fats are made up of carbon, hydrogen, and
   - a. nitrogen
   - b. oxygen

USING WHAT YOU KNOW

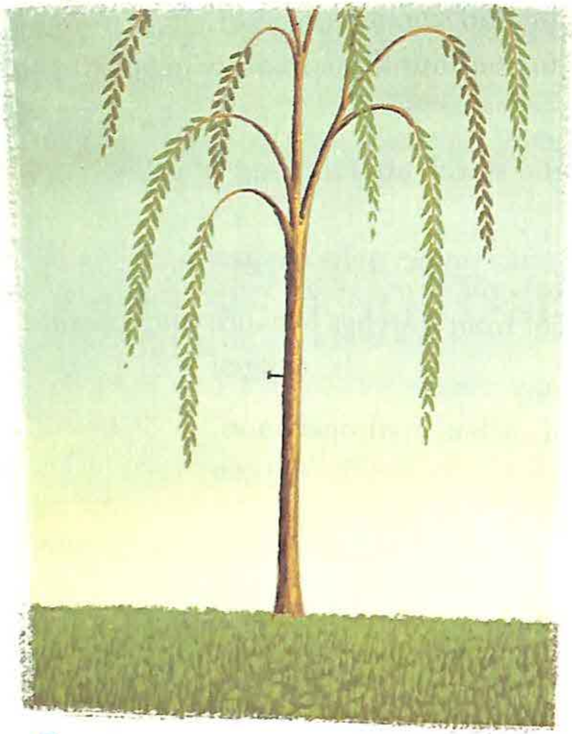
1. Glucose sugar and sucrose sugar are made up of the same kinds of atoms. What is the difference between glucose and sucrose, then?

2. A potato has starch in it. From what substance was the starch made?

3. Which of these statements is more accurate?
   - a. Green plants make food for the world.
   - b. Animals make food for the world.

ON YOUR OWN

Is the model of a molecule of glucose, on page 149, what a glucose molecule really looks like?



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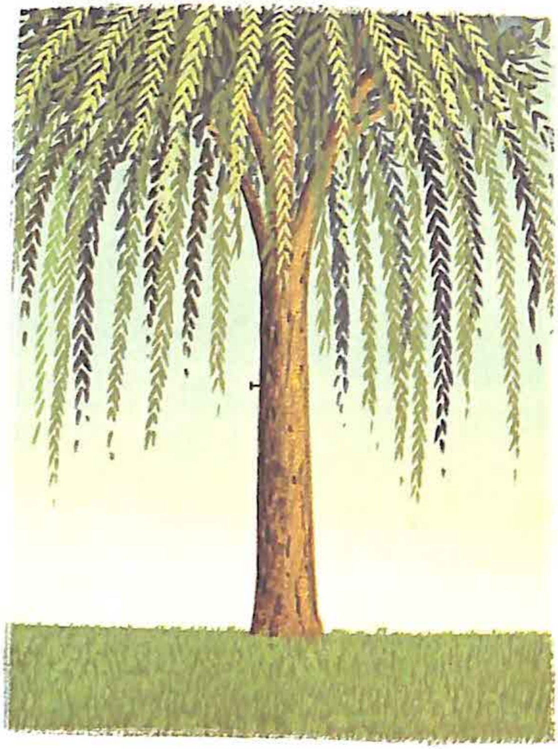

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4. A Tree Grows

Suppose that about half an inch of a small nail was hammered into a tree such as a red maple or a white oak. (It would not harm the tree.) Suppose that the nail was driven into the tree just 4 feet above the ground.■ And suppose that the tree grew about 1 foot taller every year.

How high above the ground do you think the nail would be in 5 years' time?

You can see the answer in this picture.● Is it what you expected? After all, the tree grew taller. Then why is the nail where it is?

The investigation on the opposite page will help you to answer this question. Try it for yourself.

Inside a Tree

The marks on the sunflower plant, in the investigation, showed that the plant grew taller at the tip, not at the bottom. This is how a plant or a tree gets taller. It grows at the tip. Can you see why the nail driven into the tree did not rise, although the tree became taller?

A tree grows taller at the top, just as a sunflower does. There is a reason for this. Let us look at how a tree is made.

AN INVESTIGATION into Growth in a Plant

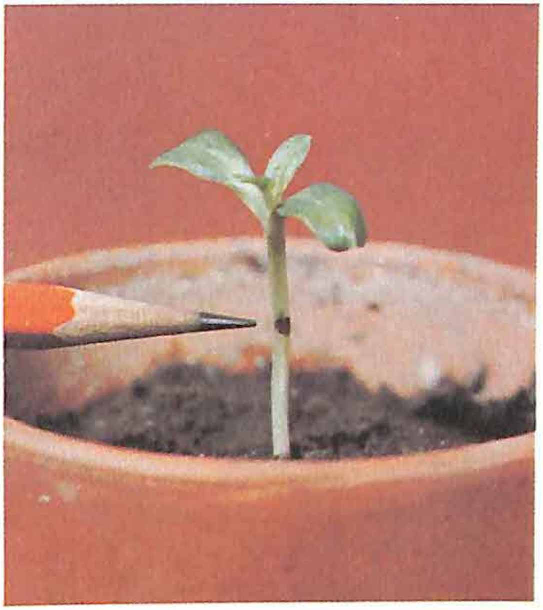
Needed: Sunflower seeds, flower pots, soil, a marking pen, a ruler

Plant some sunflower seeds in the pots. (Follow the directions on the seed package.) When the young plants are about two inches high, make a black dot on the stem with the marking pen, about an inch above the soil. ■

What do you think will happen to the height of this mark as the young plants grow? As the plant gets taller, measure the height of the mark above the soil.

Here is what happened in one trial. ●

Additional Investigation: As a plant grows, add more marks to its stem, one inch apart. Does growth take place evenly all along a stem? Or does the stem grow more in one place?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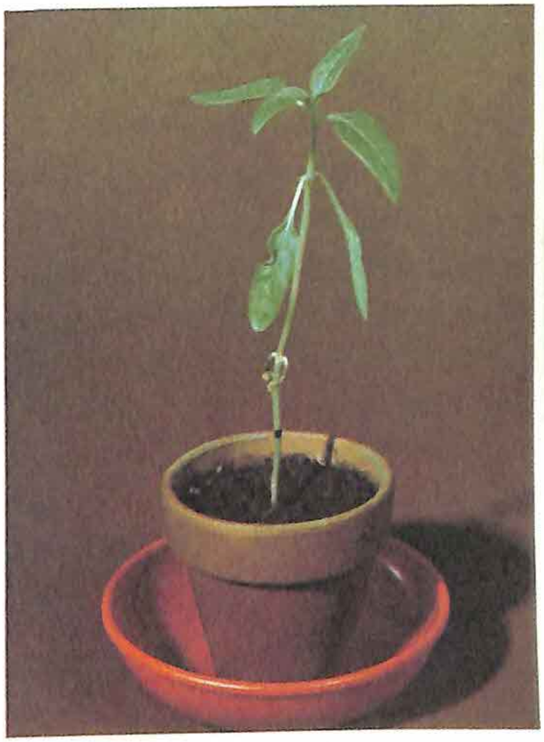
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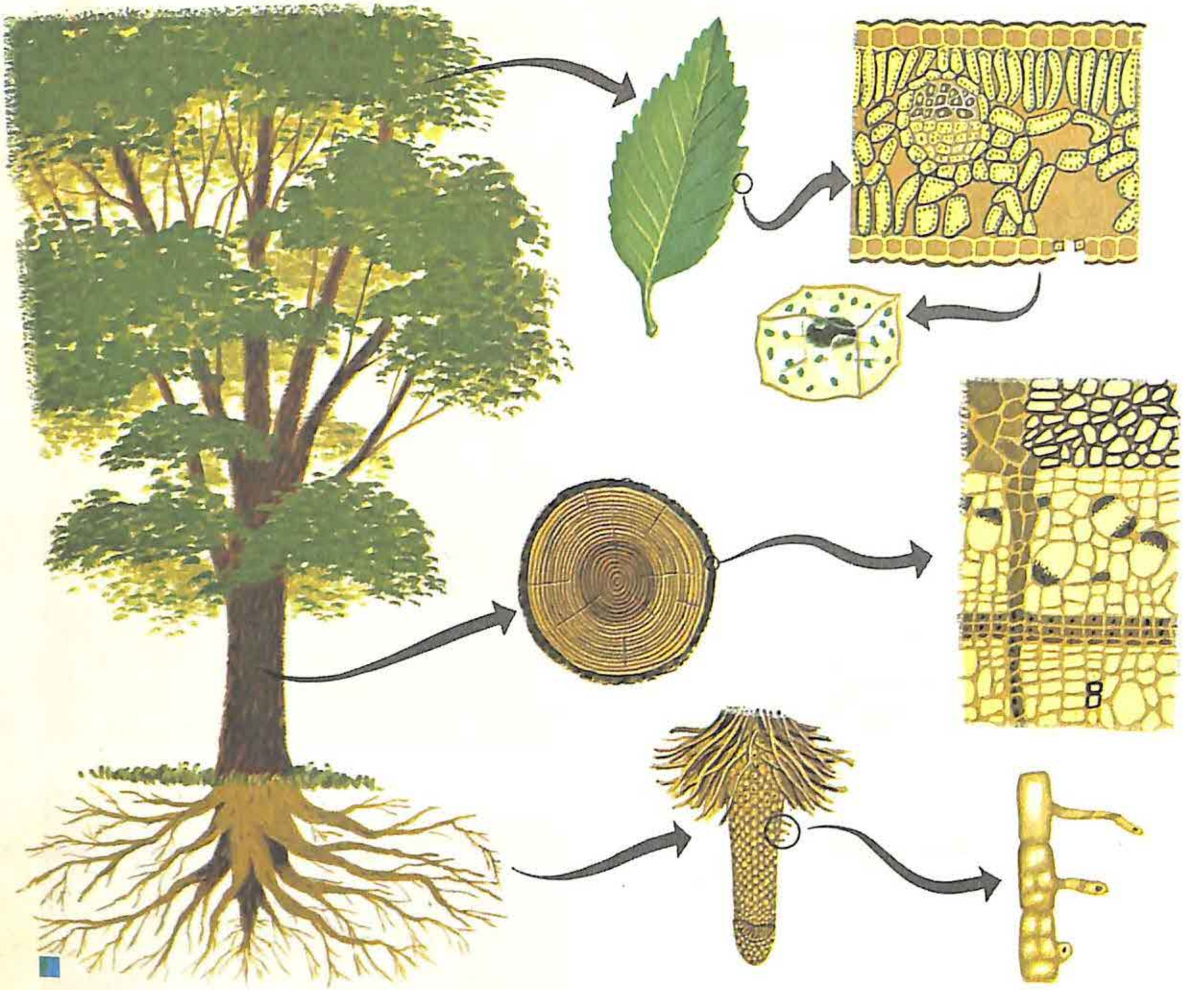


To see how a tree is made, look at little thin slices of it under a microscope. The slices of tree are made up of tiny boxlike structures. ■ These tiny structures are **cells.** As you examine different parts of a tree under the microscope, you will see that the cells are not all alike. Different parts of a tree are made up of different kinds of cells.

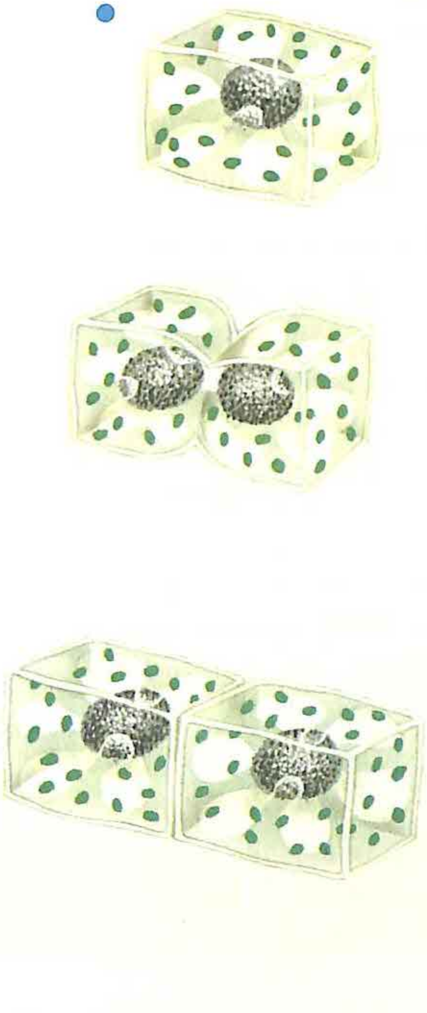
The same thing is true of a plant, a sunflower, for instance. Plants, like trees, are made up of different kinds of cells. How large are these cells? Fifty of the cells at the tip of a sunflower would fit into the period at the end of this sentence. A cell is the smallest living part of any living thing. You need to look at cells through a microscope to see them.

A tree or a plant grows longer mainly at its top. Let us look at the cells at the top, then, and see what happens there.

A Cell Grows

Suppose that we could observe one cell at the tip of a growing plant, watching it through a microscope to see if anything happens. While we watch, we see a strange thing. The cell becomes two cells. ●

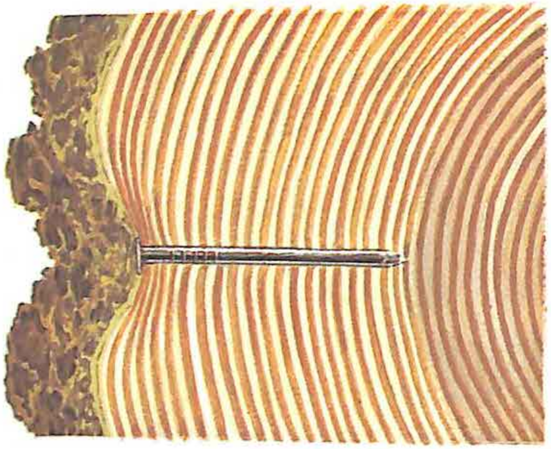
The tip of the plant is growing. It grows by **cell division.** That is, each cell at the tip divides into two cells. In a little while each of the two new cells will divide. There will be four cells where there was only one to begin with. In time, each of the four new cells will divide. (How many new cells will this make at the tip of the plant?) In a short time, the new cells grow and become as large as the cells that divided. As this happens, the tip of the plant is getting longer and longer, growing.



Notice that as the cell divides what is inside it divides as well. For this reason, the growing cells at the tip of the plant are very much alike.

When a plant is growing, the cells at the tips of its branches are dividing. These cells at the tip of the branches are alike. If you have pulled up a small plant and a larger plant like it, you know that roots grow, too. When a plant is growing, the cells at the tip of its roots are dividing. These root tip cells are alike. A plant grows taller by cell division. Its roots grow longer by cell division, and reach deeper into the soil.

The nail in the tree did not change its height above the ground as the tree grew taller. Did you observe something about the nail that *did* change? If you did not, turn back to page 152 and take another look at the picture with the square.



The nail seems to have gone farther into the tree. This is not what really happened, however. What happened is that the tree has grown out around the nail. In a few years more the nail may disappear. The tree may grow over it.

Since this is so, what must the cells in the outside layer of the trunk be doing?

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

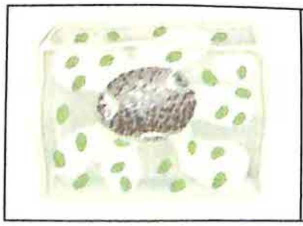
1. A tree grows in height at the
   a. tip b. middle

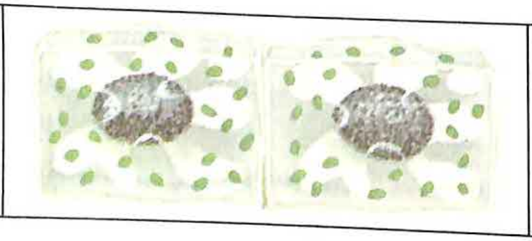
2. A tree grows in width because the dividing cells are in the
   a. outside layer b. tip

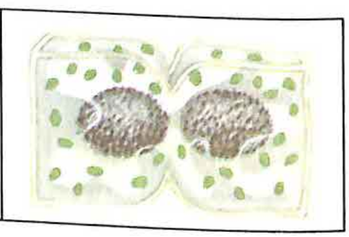
3. Into whichever part of a tree we look with a microscope, we find
   a. sugar b. cells

USING WHAT YOU KNOW

1. Here are three different pictures of a cell dividing. They are not in the right order. What is the right order?





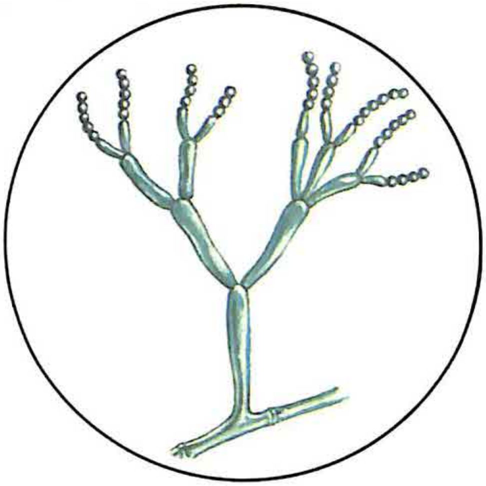


2. If you could look at a bit of a geranium plant under a microscope, what would you expect to see? Why?

ON YOUR OWN Do you think that a plant can grow if its cells stop dividing? Why?

5. A Tree Falls

For many years the white oak tree grew and grew in a woods on a farm. It grew in a wet place, but white oaks like wet places. The white oak became a tall tree, 80 feet high. It became a good home for other living things, for animals and plants. It was a home for birds, for insects, for a family of raccoons. It gave shade to deer. It gave shade to many plants that must have shade to grow, such as ferns and mosses. Such plants cannot live in bright sunlight.● The white oak received the bright light of the sun and sheltered the plants below. (Next time



you go to a woods, examine the plants that grow in the shade. They are different from the plants growing in bright sunlight.)

In time, however, the white oak was struck by lightning and fell. The farmer did not remove the fallen tree. He left it there as a shelter for the small animals he knew lived in his woods. Perhaps it would shelter some toads, or a green snake, or a garter snake. These animals eat their fill of insects. Farmers welcome such animals.

So the white oak tree lay in the woods. Have you ever thought what a woods might be like if all the trees remained where they fell? A woods would become clogged with dead trees, in time. Yet this does not happen. Dead trees disappear.

How does a dead tree disappear? Not because farmers take the trees away. The investigation on the opposite page will give you a good clue to the answer.

A Tree Starts to Disappear

A tree is made of cells. Even when the tree is dead, these cells have food stored in them. It is not the kind of food that you eat, to be sure. But it is food for certain plants, called **fungi** (FUN·jy). The molds that grow on bread are fungi. There are other fungi besides molds, however. Here are some other fungi. ■

Fungi are plants. However, there is an important difference between fungi and the green plants we know so well. Green plants make their own food. Fungi do not make their own

AN INVESTIGATION
into a Piece of Bread

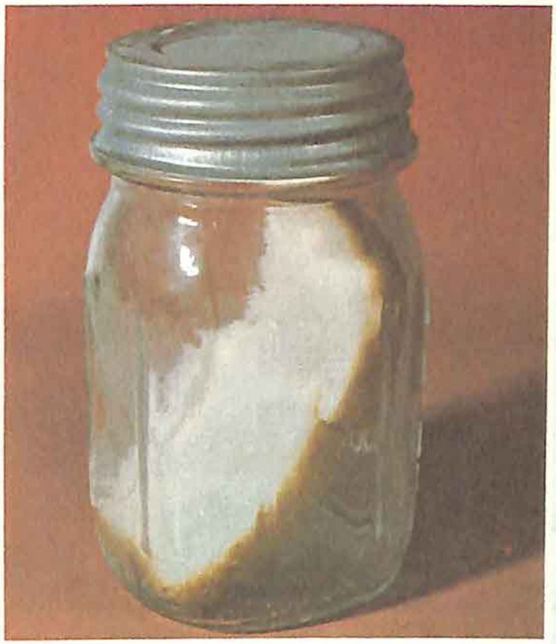
Needed: a piece of stale bread, a jar with a cover, a magnifying glass

Place the piece of bread in the jar. Add 5 drops of water to the bread. Then cover the jar, and put it in a warm place —but not in sunlight. ■

Observe the bread every day. Here is what happened in one trial. ● A growth has formed on the bread. It is a mold, living and growing on the stale bread. Use the magnifying glass to examine the mold. ▲ The tiny black balls are called spore cases. Each spore case is full of **spores.** A spore is a living cell that can grow into a mold plant.

What is happening to the bread? It is being eaten by the mold and by other growths that appear on it. In time the bread will disappear. It will be consumed by living things.

Additional Investigation: Where did the mold come from?



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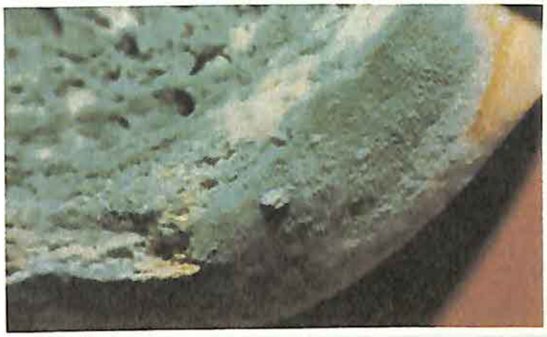

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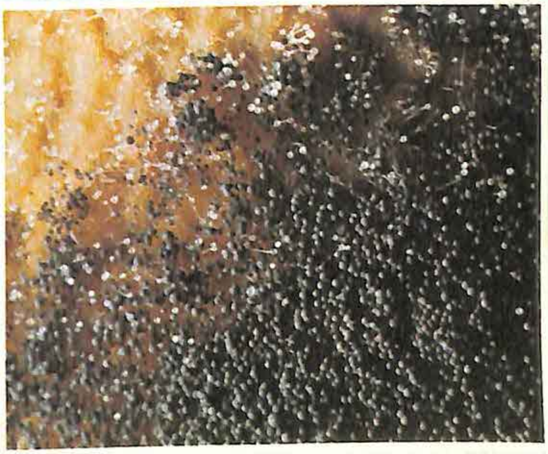

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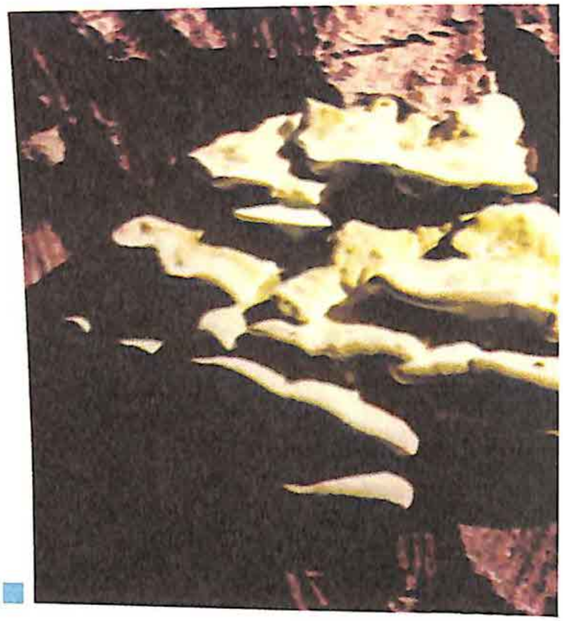
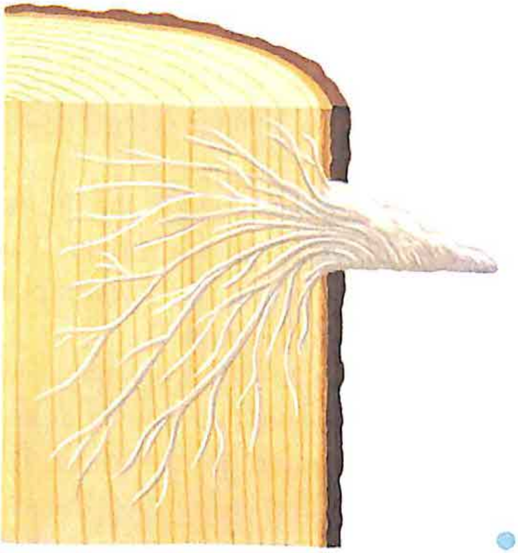




food. Green plants use **chlorophyll** (KLOR·uh·fil), a green substance in their cells, to make their food. Fungi have no chlorophyll in them. They cannot make their own food.

Where do these plants get food, then? They feed on other plants, or on food that is already made. Some fungi, such as bread mold, feed on bread, flour, and grain. Other fungi,

such as the blue molds, feed and grow on fruit. And still other fungi feed on wood in dead trees.

Have you ever seen fungi like these? ■ They are called bracket fungi. The body of the fungus (FUNG-gus) is made of threads reaching into the tree. The fungus threads travel deep into a dead tree and feed on the cells of the tree. ● The part growing out of the trunk, called the bracket, holds the spores. The spores can fall on other trees and give rise to more bracket fungi.

Fungi feed on the dead tree. Soon the tree begins to fall apart. It is starting to disappear, for it is being eaten by other plants. But that is not all that is happening.

A Tree Decays

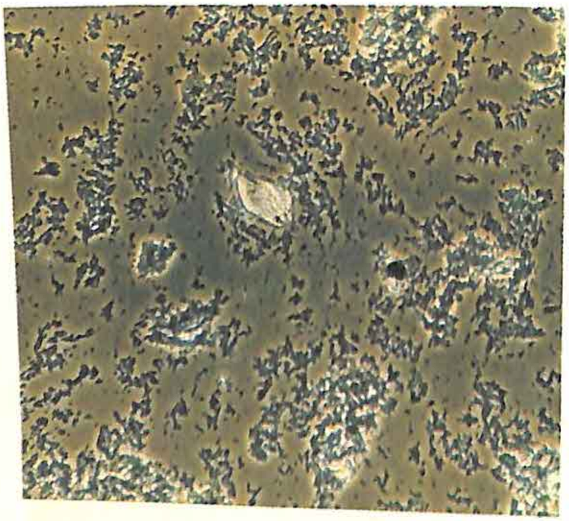
Now the dead tree is overgrown with mosses. Even ferns are growing on it, their roots pushing down into the bark and below it. They too are helping to break up the tree. Fungi too are everywhere, on the tree and under the bark.

Lift up a piece of bark: insects scurry about. Slugs feed on the tree, hidden beneath the bark. Snails are there too. ▲

◆

Push the tree and it gives way: it has little strength. Here, near the ground, it is crumbling almost into powder. This powder was once hard wood. ◆ Now the wood is breaking down. We say that the wood is **decaying** (dih·KAY·ing). This decaying wood is making the soil richer. As it decays, the wood becomes mixed with the soil. It becomes part of the soil. The wood becomes **humus** (HYOO-mus) in the soil. Humus is made up of bits of decayed plants and animals. Thus the tree is returning substances to the soil that it once took away from the soil.

It is plain to see that the dead white oak is now giving life to thousands of plants and animals. Yet there are billions upon billions of plants living in the tree that you cannot see, for they are too small. These



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plants are the decay bacteria, tiny one-celled, colorless plants found in the soil. The decay bacteria are the main plants that feed on the tree and cause it to decay. You may remember that bacteria are not able to make their own food. Seen through a powerful microscope, some of the decay bacteria in soil look like this. ■ Small as they are, and simple as they look, they are living plants.

These bacteria that cause decay are very important to us. By breaking down dead plants and dead animals, bacteria make it possible for life to go on. The bacteria cause the tree to return substances to the soil. If substances were not returned to the soil, life could not go on. If plants took from the soil and never gave anything back, there would soon be nothing more to take.

The fungi and bacteria that cause decay are very important to us. If they did not return substances to the soil, green plants could not grow. We would have no food.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Unlike a fungus, a green plant
   a. can make its own food
   b. cannot make its own food
2. Without bacteria, there would be no
   a. decay b. soil
3. We expect to find chlorophyll in
   a. leaves b. fungi

USING WHAT YOU KNOW

1. What is one difference between a green plant and a fungus plant?

2. Why are decay bacteria important?

3. Which of these statements is accurate? Why?
   a. Decaying trees and plants make the soil richer.
   b. Decaying trees and plants make the soil poorer.

6. Three Seedlings

That white oak tree that fell and returned to the soil had a useful life. It made food and wood. It gave shelter to plants and animals. It gave food to insects and fungi. Yet it did still more. It made more of itself. The white oak tree made more white oak trees.

The white oak had the help of a squirrel, however. If you have ever watched a squirrel you know that he will carry an acorn far from a tree. As squirrels do, this squirrel buried some of the white oak's acorns. ● He buried some near the tree, and he buried others some distance away. And as squirrels do, he forgot some of them, and left them buried in the soil.

●

Some of those buried acorns sprouted. A young white oak seedling grew just about where the big tree had fallen, in the woods near the stream. The squirrel had buried another acorn across the road, up on the sunny hill. Another white oak seedling grew there, near a rock. Next to that white oak seedling there sprouted the seedling of a staghorn *sumac* (SUE·mak).

A scientist who has made a study of how plants grow could tell you something about the future of those three seedlings. He could tell you these things because he knows what kind of environment they need.

The white oak seedling in the woods near the stream would grow well.

The white oak seedling on the sunny hill would not grow as well as the one in the damp woods.

The staghorn sumac on the sunny hill would grow well enough.

How could a scientist know this? The answer has to do with the environment of each seedling. Environment, remember, means the conditions in which a plant or an animal lives. Let us see how important environment is.

The Importance of Environment

Here are three animals. ■ Can you think of an environment in which each one *cannot* live?

The bird cannot live under water. The fish cannot live on land. The frog cannot live in a desert. Each

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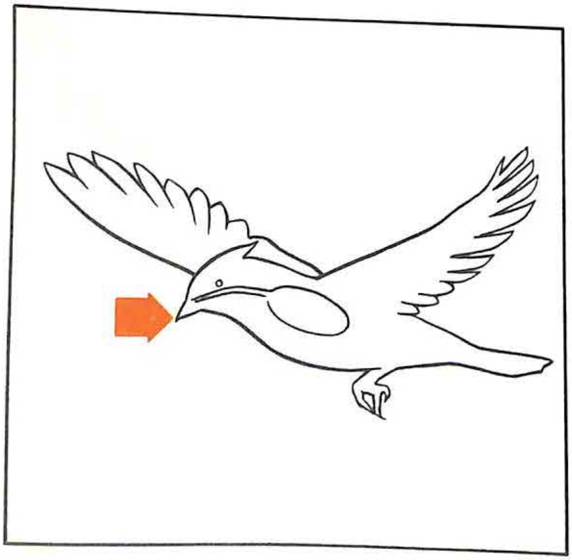

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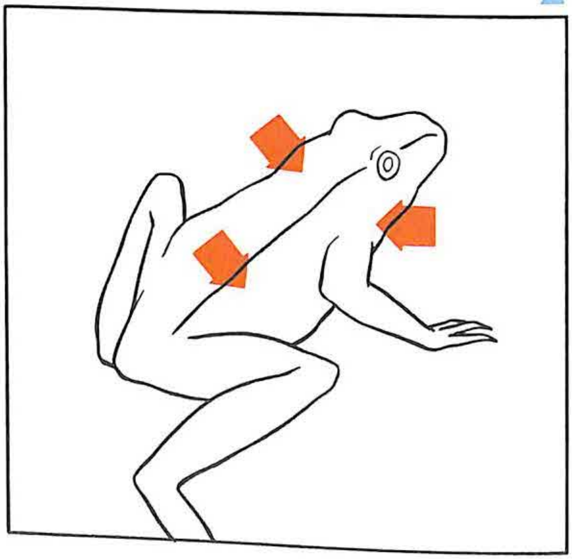

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of these animals is so made that it can live in a certain environment. We say that each animal is **adapted** to a certain environment.

The bird is adapted to living in air. It has lungs. ● Lungs take oxygen from air. Lungs cannot take oxygen from water. Lungs adapt the bird to living in air.

A frog has lungs and breathes air. But it must also use its skin in breathing. The moist skin of a frog takes oxygen from the air. ▲ If a frog's skin dries, the frog will die. It will not get enough oxygen. So a frog's skin must remain moist. A frog is adapted to living where its skin remains moist. There are no frogs living in deserts.

The fish, however, is adapted to living in water. The fish has gills. ◆ Gills can take oxygen from water. The oxygen is dissolved in the water. Gills adapt the fish to living in water.

You can see why a bird cannot live under water, and why a fish cannot live on land. What about a frog? Why can't a frog live in a desert?

Each of these animals—frog, fish, bird—is adapted to a special environment. Indeed, this is true of every living thing. Each grows best in its special environment.

You may be wondering about man. Doesn't man live in many different places on this planet? Is there a

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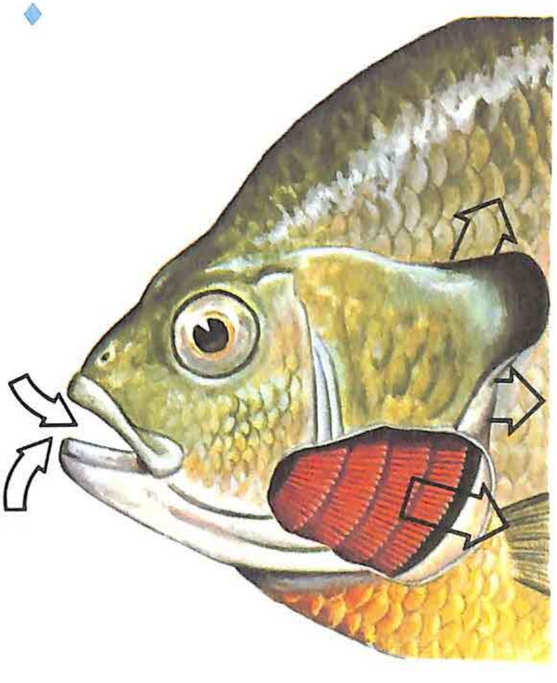

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special environment for him, then? There is. Notice, for instance, that when man goes under water he takes air with him. ■ When he goes into space, he takes air and food and other things as well. There is an environment to which man is adapted.

Each living thing grows best in its special environment and grows poorly in other environments—if it grows at all. Environment can make the difference between growing and not growing, between life and death.

Now we know something of the importance of environment. Let us get back to our three seedlings. There is the white oak seedling in the forest near the stream. There is the white oak seedling on the sunny hill. And there is the staghorn sumac seedling on the hill. What about their environments?

An Environment for a White Oak Tree

A scientist who studies environments, and how living things are adapted to environments, is called an *ecologist* (eh·KOL·eh·jist). Ecologists know the best environment for a plant or an animal.

For example, suppose you told an ecologist that you had seen a fine weeping willow tree. He could tell you a good deal about the environment of the tree without ever having seen it. He could tell you, for instance, that the willow was growing where its roots had enough water. This is part of the environment that a willow tree must have in order to grow well.

An ecologist could describe the environment in which the white oak had grown. Ecologists have learned that a white oak tree lives best in an environment with soil that holds a fair amount of water. They have learned that staghorn sumac lives well enough in dry soil, but not in soil as dry as a desert. A cactus, however, can live in the dry deserts of the southwestern parts of the United States.●

Do you see how an ecologist could predict the future of the white oak seedlings and of the staghorn sumac seedling, too? The ecologist knows that the white oak seedling in the moist soil near the stream is in the environment to which it is best adapted. That environment has been made even better by the decayed tree. The decayed tree has added humus to the soil. With more humus in it, the soil can hold more water. Moreover, the sun's light can reach the white oak seedling through the space where the old white oak once stood.

Up on the sunny hillside, the other white oak seedling receives plenty of sunlight, too. But its soil has little humus in it and is not so rich. Its soil cannot hold much water. The white oak seedling on the hill does not have its best environment. The staghorn sumac, however, is adapted to just this environment. It is adapted to rather dry soil. The sumac seedling can grow well enough here on the hill. The white oak seedling on the hill cannot grow well.

A living thing lives and grows best in the environment to which it is adapted. The better that environment, the better the living thing will grow. This is true for white oak trees, for birds, for frogs, for fish, for every plant and animal. It is true for you, too.

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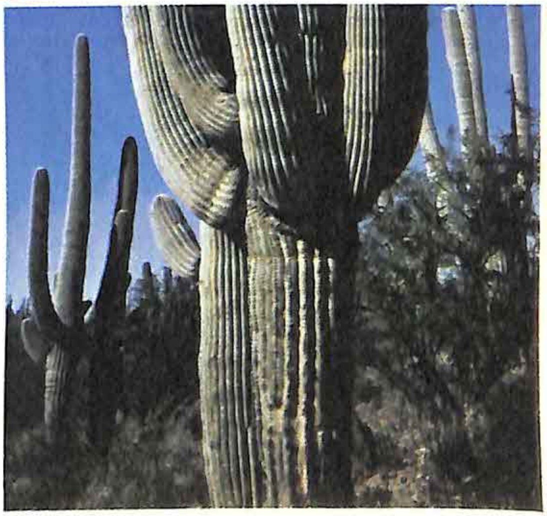


BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. We say a living thing is adapted to an environment when it is
   a. fitted to live in the environment
   b. not fitted to live in the environment
2. A staghorn sumac is adapted to
   a. moist soil b. dry soil
3. An ecologist is a scientist who studies
   a. the environment only
   b. living things and their environment

USING WHAT YOU KNOW

1. Name three animals. For each animal, name an environment in which that animal cannot live.
2. How are *you* adapted for life on land?

ON YOUR OWN

Trees growing on city streets usually do not grow as well as trees growing in the woods. Why?

7. The Main Concept: A Living Thing in Its Environment

What would you expect to find in a pond like this one? ■ You might expect to find fish, some water snails, perhaps some tadpoles. Certainly you would expect water plants.

You would be very much surprised to find a cow or a cactus plant living under water. You know that a living thing is adapted to a special environment. You expect certain living things, like a big tree, to live in a forest, not in a desert. You expect a whale to live in the sea, not in a forest.

All living things are adapted to their environment. This concept helps us in understanding the where and how of living things. Knowing this concept, we can understand the needs of a cactus, or a fish, or a sea gull. We can understand the life of a tree.

Because we know something of the environment of a tree, we can plant the seed where it will grow best. If we want a white oak, we plant the acorn in a wet place. If we want a staghorn sumac, we plant its seed in a dry place. If we want wheat, we prepare the field so that the wheat seeds will grow well.

Give a tree its proper environment and the tree will grow well. Its roots will take in water and the substances dissolved in water. Its leaves will take in carbon dioxide.

Using energy from the light of the sun, the green plant will make food. In its green leaves, carbon dioxide and water will combine to form sugar. Once sugar is formed, the green plant will combine it with nitrogen to form proteins, or it will change the sugar to form starches or fats.

We depend on green plants for our very life. All living things depend on green plants. Green plants are the food factories of the world.

Sooner or later a tree dies and falls. Yet this is not the end. Fungi and bacteria of decay now live on the tree. The tree becomes a good environment for other living things. Fungi, bacteria, insects, and small animals live in it—and on it. At last the tree crumbles. Its body adds humus to the soil. Other plants grow well in the enriched soil.

An acorn falls on the place where the tree stood. The soil is enriched by decayed wood. The acorn grows in the enriched soil. A seedling grows tall. Once again a living thing thrives because the environment fits it. And the living thing fits the environment.

Every living thing is adapted to its own environment.

Fixing the Main Concepts

TESTING YOURSELF Study the statements below and choose the correct responses. Your study will help fix in your mind the main concepts of this unit.

1. To start growing, a seed needs
   a. water b. light
2. To grow, a green plant needs
   a. light b. darkness
3. A cactus and a fir tree need
   a. the same environment
   b. different environments
4. Plants make sugars from water and
   a. carbon dioxide b. oxygen
5. Sugars can be made by
   a. all plants b. green plants
6. To make proteins, a plant uses
   a. nitrogen b. wood

7. A tree grows taller at
   a. its top — b. its middle

8. When a tree is growing, its cells are
   a. dividing — b. subtracting

9. As a tree decays, it is food mainly for
   a. frogs and snakes — b. bacteria and fungi

10. A decaying tree adds humus and substances to the soil. This makes the environment
   a. better for seedlings — b. worse for seedlings

FOR YOUR READING

1. *Lookout for the Forests. A Conservation Story,* by Glenn O. Blough, published by McGraw-Hill, New York, 1955. This book takes you farther into the forest and forest life. The usefulness of the forest environment is shown as well as its beauty.

2. *Lives of an Oak Tree,* by Ross E. Hutchins, published by Rand McNally, Chicago, 1960. Here is another view of the life cycle of an oak tree and how it is fitted to the environment.

3. *Up Above and Down Below,* by Irma E. Webber, published by William R. Scott, New York, 1943. Here is a book that introduces to you the kinds of plants above the soil and those which live beneath the soil. It compares the different environments above and below the Earth's surface.

GOING FURTHER

An Investigation

Did you realize that yeast is a fungus? It is a colorless, microscopic plant.

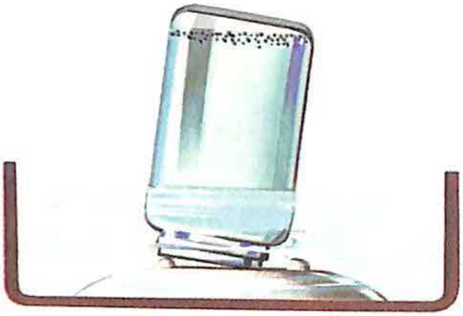
Yeast can grow well in a solution of sugar. As yeast grows, it gives off carbon dioxide gas. The faster yeast grows, the more carbon dioxide it gives off.

If you can observe the amount of carbon dioxide gas given off, you will know how well yeast is growing. The environment in which yeast grows best will result in the most gas.

To observe carbon dioxide gas, make a sucrose sugar solution by dissolving 4 level tablespoonfuls of sucrose in a quart of water.

Put some sugar solution in a small jar. Be sure that the jar is filled to the brim. Add a teaspoonful of powdered yeast to the solution. Cover the jar with a dish. Turn the jar over. Put the mouth of the jar under water, as in the diagram.

As the yeast grows and gives off carbon dioxide, the gas will collect at the top. Some of the solution will be forced out.



Now you have a way of observing the amount of carbon dioxide gas given off by growing yeast.

You can find out some interesting things about the environment of yeast. Will a solution with twice as much sucrose in it produce more gas? That is, will yeast grow more with more sugar? Will yeast grow more in four times as much sucrose? eight times as much? sixteen times as much? one half as much?

Is a sugar solution the best environment for yeast? Add a pinch of ammonium nitrate to a jar of sugar solution. Do nitrates improve the environment for the growth of yeast?

Will vitamins improve the environment?

Would a good scientist draw a conclusion from one or two observations?

How do you know it was the yeast that produced the carbon dioxide? Could it have been the sugar?

We are sure other questions will occur to you. You are on your own.

Beginning a Hobby

Many people pass a tree without knowing what kind it is. Yet trees can be very interesting. Trees are easy to identify in both summer and winter. Why not begin a study of trees? Become an expert on the trees of your neighborhood. You may find it fun.

A good way to start is to get one of these books. The pictures in them of trees, leaves, bark, and buds will give you a good start.

1. *The First Book of Trees,* by Maribelle B. Cormack, published by Franklin Watts, New York, 1951. Here is a book that will introduce you to familiar trees.

2. *Wonders of the Tree World,* by Margaret Cosgrove, published by Dodd, Mead & Company, New York, 1953. In this book you will find forty-seven kinds of trees and their relatives identified for you.

3. *Our American Trees,* by Ruth Dudley, published by Thomas Y. Crowell Company, New York, 1956. Although this book does not deal with identification, it will give you much useful information about trees.

These books are only a beginning. They will point to other ways of learning about trees.

CONCEPTUAL SCHEME

A living thing is the product of its heredity and environment.

(*Text pages 174–213*)

Unit Six

THE JOURNEYS OF A SALMON AND A DUCK

UNIT CONCEPT

A living thing reproduces itself and develops in a given environment.

Children begin to understand that animals have life cycles which are repeated with each new generation. They examine in detail the life cycles of a particular fish and a particular bird. They see how the structures and behaviors of different animals fit them for different environments. They become more deeply aware that every organism in its own special ways is interdependent with and adapted to its environment.

A VIEW OF THE UNIT

A Preview of the Concepts

The egg of a salmon develops into a salmon. The egg of a duck develops into a duck. Why? We know eggs have within them bits of matter that transmit to the offspring the characteristic traits of the parents. Somehow, in ways scientists are just beginning to understand, substances within the egg shape the body structure and direct the behavior pattern of the individual organism as its life unfolds from embryonic existence through birth to maturity. Heredity, then, the familiar fact of "like begets like," makes an organism the specific kind of creature that it is.

Nevertheless, we know that it takes much more than heredity to turn an egg into an adult. No salmon, duck, oak tree, or human being can come into being apart from a suitable environment. At every point in its life history an organism is what it is because of the dynamic interplay between its heredity and its environment. It has been aptly said that what you are is 100 per cent due to your heredity and 100 per cent due to your environment. So it is for every living thing.

Food chains

One of the most basic demands upon its surroundings that an animal makes is for the energy stored in food. As children investigate the food supply in a pond and read about food for young salmon, they begin to develop the concept of food chains. They learn that every food chain begins with a green plant, i.e., an organism able to capture the sun's energy. The transfer of that energy, stored in foods, to a series of successive consumers—animals and nongreen plants—relates organisms of many kinds to one another.

Life Cycle of the Salmon

To find out how young salmon come to be born in an environment that provides suitable food, the children trace the arduous and remarkable journey of mature salmon as they return from the ocean to their native stream to spawn. As soon as they deposit their eggs and sperm, the parent fish die. It is the end of the story for the individual salmon, but the life of the species goes on.

From the salmon eggs strange-looking young hatch. These soon change into fish adapted to life in the stream. At this stage they are known as parr. In due time parr turn into smolts. Equipped for life in the sea, the smolts leave the stream for the sea, where they mature into adult salmon. This is "where we came in," for the story began with adult salmon in the ocean starting the journey back to the stream of their birth. Told in this way, the cyclic nature of the story is especially clear. While the life history of an individual animal begins with the egg and ends with the animal's death, the life of a species is a cycle that goes on and on, as the children will discover in this unit.

Adaptation to Habitat

It is a short step from the concept of an animal's life cycle to the concept of an animal's adaptation, at every stage in its life cycle, to its special environment or habitat. As children investigate the structure and behavior of a fish, they focus attention on the animal's fitness, in both structure and behavior, to its habitat. Then they turn to the story of the journey of another migrating animal, the mallard duck, and study its adaptations and trace its life cycle.

Life Cycle of the Duck

Ducks, like salmon and other organisms, reproduce and develop in a given environment. From their winter homes in the south, mallard ducks fly to marsh lands to the north and west to lay their eggs. As children begin to explore how the duck is fitted to its habitat, they may reasonably expect the duck's adaptations to differ widely from those of the salmon. Structure and behavior that fit an animal to life on land and in the air are quite unlike those that fit an animal to life in the ocean and stream. As children trace the life cycle of the duck, they strengthen their concept of the adaptation of every kind of organism to its special environment.

Inborn Animal Behavior

The remarkable facts of animal behavior have led scientists to ask how animals know enough to behave as they do. Children may imagine that young animals learn as much from their elders as young children do, but scientists so far are convinced that animals inherit a great deal of their "know-how." Children begin to understand inborn behavior when they investigate the response of a plant to the stimulus of gravity. Plant behavior is clearly not learned. Children then see how the concept of an inborn response to a given stimulus works for animals, too. Animals do, of course, have learning ability; but the evidence is that migration in birds, and other complex adaptive behavior in animals, is not learned but inborn.

As children note the twofold nature of adaptation, by structure and behavior, they deepen their understanding of the concept of a living thing as the product of its heredity and environment.

SUPPLEMENTARY AIDS

All films and filmstrips are in color and are rated as suitable for the level of conceptual development in the textbook. Names and addresses of distributors and suppliers are on page F-25.

Films

Hibernation and Other Forms of Dormancy (10 min.), E.B.F. Shows how various animals adjust to their environment during the winter months; some go into hibernation; and some, in the summer, go into a deep sleep called estivation.

Life Story of the Paramecium (11 min.), E.B.F. Shows that the basic unit of life is the individual cell; shows how the paramecium feeds, grows, breathes, moves, gives off wastes, reacts to stimuli, and reproduces.

The Life Story of the Snail (11 min.), E.B.F. Shows the life cycle of a snail in an aquarium; illustrates its methods of locomotion, feeding, growth, and reproduction.

Migration of Birds: The Canada Goose (11 min.), E.B.F. Illustrates the yearly cycle of the migrating bird; presents facts and theories about the phenomenon of migration.

Animal Habitats (11 min.), F.A. Illustrates the relationship between living things and the habitat, or environment, in which they are found; describes the specific adaptations of animals to the various conditions of life.

Environment and Survival—Life in a Trout Stream (12 min.), F.A., 1964. Shows how instincts help protect fish from their enemies, and how they determine their feeding locations, and their eventual migration to spawning areas.

Filmstrips

Animal and Plant Relationships (38 frames), McGraw-Hill, 1961. Photography shows how an organism must either adapt to an environment, move out of it, or perish; shows how plants and animals change with each stage of change in environment; shows food chain plants and animals.

Life in an Aquarium (45 frames), McGraw-Hill, 1962. Shows how to set up a classroom aquarium; why green plants are necessary for healthy fish; how fish are adapted for life in water. Explains oxygen cycle.

Birds of Our Ponds and Marshes (40 frames), S.V.E., 1963. Explains that birds have a preferred habitat, and if this is destroyed they disappear; a preferred habitat provides best food, shelter, and nesting place; shows how structure of parts of the bird is best fitted to particular environment.

Migration of Birds (47 frames), S.V.E., 1963. Explains how scientists and bird watchers have solved the mystery of migration; shows hazards of migration.

Mr. and Mrs. Mallard and Their Family (33 frames), S.V.E., 1963. Photography shows the complete life cycle of the duck; how adapted to its environment; behavior patterns; migration is caused by certain stimuli of weather changes.

Mr. and Mrs. Robin and Springtime Family (31 frames), S.V.E., 1963. Shows the inborn behavior in the robin's process of building its nest; care of babies; shows complete life cycle of robin.

Starred (°) titles are considered especially suitable for conceptual development on the level of the pupils' textbook. Other titles are useful for special sections of the unit. Names and addresses of the publishers are on page F-24.

°*The Community of Living Things in City Parks and Home Gardens*, by Robert S. Lemmon, Creative Educational Society; in cooperation with the National Audubon Society, New York, 1956. Volume three of five volumes. A full-page photograph accompanies each page of text. The chapter headings, indicating the extensive subject matter, are: "The Natural Community in City Parks"; "The Natural Community in Home Gardens, Plant Life"; "Birds and Mammals"; "Cold-blooded Animals"; and "The End of the Season." Teachers and pupils will relate much of the content of the book to environments accessible for firsthand study. (Advanced)

°*The Community of Living Things in the Desert*, by Alexander and Elsie B. Klots, Creative Educational Society; in cooperation with the National Audubon Society, New York, 1956. Volume five of five volumes. A surprising variety of plants and animals, including some of the most unusual species on Earth, inhabit the desert. The book includes background material needed to make clear the causes of deserts, the conditions of life that prevail there, and the interrelated activity of the plants and animals. Excellent photographic illustrations and desert camera studies. Good for reference. (Advanced)

°*The Fisheries Story*, by George Shaftel and Helen Heffernan, from the *Man Improves His World* series, L. W. Singer, 1963. The fish resources of the sea are described principally in terms of potential food for peoples of the world. The narrative includes considerations of plankton, sea vegetables, and shellfish, as well as many kinds of fish; and research to improve fishing practices and uses. Good for reference on selected topics. (Advanced)

°*The Friendly Dolphins*, by Patricia Lauber, Random House, 1963. A fascinating account of dolphins from ancient times to the present. They apparently like people, and this characteristic provides unusual opportunity for close study of the habits and intelligence of these mammals. One researcher is experimenting with teaching them to speak English. (Average)

Here Come the Bees! by Alice E. Boudley, Scribner's, 1960. Takes the reader into the honeybee's world for a close-up of bees and their ways. Describes the intricate social life, responsibilities of members of the hive, and the varied activities related to honey-making. (Average)

On Six Legs, by Donald Nasca, F. A. Owen, 1964. A lively story of the Summer Reading Group and its investigation of insects. The librarian, Steve's entomologist uncle, a beekeeper, and a farm agent help the girls and boys with their project. Much conversation and observation results in acquisition of many facts about insects. (Advanced)

Red Tag Comes Back, by Arnold Lobel, Harper & Row, 1961. The story of a salmon's journey to the sea and her return, years later, to her birthplace. The red tag was attached to the fish by a man from the Fish and Wildlife Service. An Indian boy watches for the return of "Red Tag." (Easy)

°*Terry and the Caterpillars*, by Millicent E. Selsam, Harper & Row, 1962. A delightful story describing the life cycle of the cecropia moth, and the story of Terry as she finds out more and more about "what happens next" to her caterpillars. Arnold Lobel's beautifully drawn pictures add to the beauty and intriguing quality of the book. (Easy)

What Is a Butterfly, by Gene Darby, Benefic Press, 1958. The major emphasis is upon metamorphosis. Likenesses and differences between moths and butterflies and the activities of moths harmful to man are noted. (Easy)

°*The Wildlife Story*, by George Shaftel and Helen Heffernan, from the *Man Improves His World* series, L. W. Singer, 1963. An introductory story, "The Curse of the Cats," is based on actual fact and furnishes an illustration of how plants, animals, soil, and water are interrelated to affect man's welfare. Material on the preservation of wildlife includes the topics "Migratory Birds," "How Protection Helps," and "Wildlife Conservation Projects in Other Countries." (Advanced)

▶ INTRODUCING THE UNIT

As you read the opening page of the unit with the class, encourage speculation on the questions in the text about the opening picture. You may wish to raise some additional questions.

How many eggs are in one row across the page? Children will count about five eggs across. Are the eggs really as large as shown? Tell the children that if the picture were not magnified you could place about 50 of the eggs in one row across the page. (Each egg is about $\frac{1}{8}$ of an inch in diameter.)

What do you see inside the eggs? Some eggs have tiny salmon in them. (The others did not develop.) How big is a grown salmon? It will be obvious to the children that before the salmon can start their strange journey they must not only hatch but they must also grow. What must they do to grow? The young salmon must eat to grow, and as they grow they do not only increase in size, but (as you can see from the picture) their appearance changes. What do young salmon eat? How do their bodies change as they grow? These questions lead to the beginning of the first section of the unit.

(Text pages 176–81)

SUBCONCEPT

Living things depend on other living things for their food, in food chains that in the end depend on green plants.

Section 1: IN THE SPRING

Children understand that animals and some plants depend on other living things for their food.

Introducing the Concept

What does a baby chick do just after hatching? a puppy or kitten as soon as it is born? any newborn animal you know about? It will feed or be fed. Do unhatched chicks or salmon in the eggs eat? They use the food stored in the egg.

Read the opening paragraphs of the section **In the Spring,** down to the investigation. The just-hatched creatures, those with "bags" (yolk sacs) (in the picture on page 176) still do not eat. Why? They are still using stored egg food. You may, if you wish, identify the "bags" as yolk sacs and ask the children to compare the pictures with those on page 185. Just after the yolk sacs disappear, the tiny salmon (as in the third picture on page 185) feed for a time on organisms too small to be seen with the unaided eye. Invite speculation on the question:

What is the source of food for the salmon after the yolk sac is used up?

Do not confirm or correct the children's responses, but start immediately on the investigation, which will take several days to complete.

Processes emphasized

Observation (field trip)
Analysis of observations
Investigation (with design of an experiment)
Categorizing
Hypothesizing
Theorizing
Developing models

Developing the Concept

Living things need a food supply.

Equipment and Materials

See text page 177; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. If possible the children should collect the pond water themselves, using the **On Your Own** section (text pages 285–299) as a guide. This may be a class trip or an independent activity. Next best to a pond as a water source is a slow-moving stream. You may also use aquarium water from a store that sells tropical fish or from your own classroom aquarium.

Let the children examine the water with the hand lens or microscope before, as well as after, the investigation. Why do two of the jars have no food added? They act as a check (control) for comparing results. Otherwise, we do not know that food is needed for organisms to grow. What is your hypothesis about the jars to which you have added food? Some children may know bacteria and other organisms will multiply, but let them confirm this when they read the section **Food for Young Salmon.**

The picture on the lower part of page 177 is a microscopic view of the cloudy water in the upper picture. You may also see in your water one or more of the organisms shown on page 179; these are (left to right): *Paramecium, Stentor, Ameba,* and *Vorticella.* Other organisms often seen in pond water (bacteria, protozoans, algae, microscopic worms, water fleas, etc.) are pictured in the **On Your Own** section, page 285 in this book; in *A Sourcebook for Elementary Science,* pages 57–62; and in *A Sourcebook for the Biological Sciences,* pages 253–55 and 333–53. (Do not worry if children see some organisms you cannot identify—there are over 15,000 different kinds of protozoans alone!)

From the results of your own investigation develop a food chain, including the rice or the egg yolk used. Where did the rice get its food? Where did the egg yolk get its food? Draw the food chain on the chalkboard as children supply the links. For each link use an arrow to point to the consumer, as shown here.

corn plant ⟶ hen ⟶ egg ⟶ bacteria ⟶ paramecia

If there is evidence that rotifers or *Daphnia* or other animals eat the paramecia, they can be added at the right-hand end of your chain.

Food chains lead ultimately to green plants.

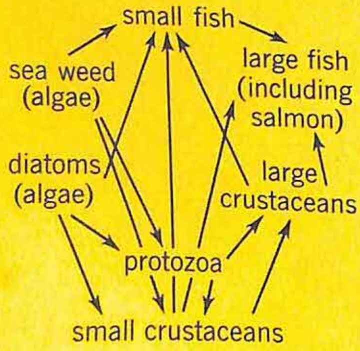
Food for young salmon. Now turn to text page 178 and develop the food chain of the salmon. The food chain of an animal leads ultimately to green plants. As children read this subsection, they should note that the young salmon eat microscopic organisms and tiny crustaceans and insect larvae in the stream, and these in turn eat protozoans and algae. Algae are best described as green plants with very simple bodies; there is no specialization of parts. This means that the roots, stems, leaves, etc., of higher plants do not develop in algae, even the large ones. Many algae, such as diatoms and desmids, are single-celled and microscopic in size. There are also many large (macroscopic) algae, such as seaweeds.

The text states that the young salmon eat small animals. Might they also eat plants? (Yes, algae.) What do the protozoans eat? (Perhaps other protozoans, but, ultimately, they too must eat green plants.) Children easily infer that all food chains begin with green plants. Why must a food chain begin with a green plant? (Only green plants can store the Sun's energy in foods, as learned in Unit Five.)

Extending the Concept

Identifying links in food chains. If children bring in specimens (such as spiders and caterpillars), ask where each belongs in a food chain. (Spider eats insect, bird eats spider; caterpillar eats decaying leaf, bird eats caterpillar.) Why are there laws to protect birds? Birds are vital links in food chains that control many insect pests.)

Charting food webs. Develop food chains for organisms living in the children's own backyards, the school grounds, a nearby park, a nearby field, forest, lake, etc., where they can observe feeding habits themselves. They may supplement their observations by reading. The children will soon realize that many animals have a varied diet so that food chains cross one another. Thus, if you let them, children can discover for themselves the concept of the food web. Write on the chalkboard the names of the organisms in the food web for an ocean environment, as shown here. Ask children to draw in arrows and show where adult salmon would fit into the web.



Upsetting food webs. What will happen when an organism is added to or subtracted from a natural feeding community, that is, from a food web? Snakes and spiders, for example, are often unpopular, but it is usually a mistake to kill them and might be a calamity if they were entirely removed from an area. Why?

(*Text pages 180–81*)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. a

Using What You Know. 1. 64 2. grain → mice → snakes → hawks. 3. plant → bacteria → protozoans → young salmon.

Section 2: THE GREAT JOURNEY BEGINS

(Text pages 181–88)

SUBCONCEPT

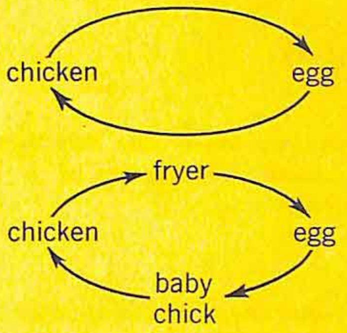
Every species of animal has a life cycle in which the same pattern of development (successive changes in structure from egg to adult) is repeated over and over again.

Children understand the circular nature of a life cycle and begin to be aware that all animals have life cycles.

Introducing the Concept

Draw two large semicircular arrows on the chalkboard, as illustrated (in the margin). Write "chicken" at the point of one arrow and "egg" at the point of the other. Which came first, the chicken or the egg? (Neither.) Notice that this diagram is *not* a chain, like a food chain. What is it, then? (A circle or a cycle.) Can we fill in more stages? Erase parts of the semicircles to make room to write "baby chick" at the bottom and "fryer" at the top. Do you know another animal that we could draw a circle like this for? Children may know the cycle of egg, larva, pupa, adult, for a moth or butterfly. Does it make any difference (and why) where we start if we want to tell the complete life story of a salmon? No, because the story is a circle that goes on and on. You might tell the children that salmon live part of their lives in the salty oceans and part in freshwater streams. Call for hypotheses:

Where do salmon spend their lives?



Developing the Concept

As you read the section up to **The Young Salmon and Their Journey** (page 184), you may wish to point out that this is the last lap in the story of individual salmon; but since the old fish spawn before dying, our reading thus far is part of an ongoing story. The life of the species, as distinct from the life of the individual, is cyclic. The crucial stage of the cycle, what really makes it a cycle, is reproduction. Even for species that do not die as soon as they produce offspring, this is, of course, true. The story of the salmon makes the point more dramatically than the life histories of animals that do not spend the last of their vitality getting to their breeding ground.

Salmon travel great distances from feeding grounds in salt water to spawning grounds in fresh water.

Processes emphasized

Observation
Analysis of observations
Library research
Development of models (life cycles)
Investigation

Adult salmon in the ocean are busy eating and escaping enemies. The successful ones not only elude the larger fish but eat more than enough, storing up fat to use as fuel on the long homeward journey.

Call attention to the picture of the fish ladder on page 183. What do you see in the background? (A large dam.) What does a dam do that would make it necessary for men to build the fish ladder? (The dam makes it impossible for the fish to climb upstream.) Describe the fish ladder in the picture. It is a series of pools connected by low falls.

The young salmon and their journey. Let the children examine one or more kinds of fish eggs. They may know several tropical fish whose young are born alive. After they read **The Young Salmon and Their Journey,** tell them that most of the 10,000 known kinds of fish lay eggs.

The life cycle of a salmon is completed after the eggs hatch and the salmon young return to salt water to develop into adult salmon.

How a salmon egg hatches. Suppose a hen's eggs were about to hatch. What is the position of the chick inside? It is curled up in an

Equipment and Materials

- . . . fisherman's salmon eggs or other fish eggs sold as bait
- . . . fish eggs sold as food (fish roe, caviar)
- . . . hen's egg

egg-shaped ball. Read the first two paragraphs of **How a Salmon Egg Hatches** (page 185), and look again at the unit opening picture of salmon eggs. If each egg is only about $\frac{1}{8}$ of an inch wide, do you see how a just-hatched fish could be $\frac{3}{4}$ of an inch long? The tiny salmon uncurls when it hatches. Notice, in the unit opening picture, that there are no embryos (developing salmon) in some of the eggs. These are the ones that sperm did not reach. They show that eggs have a uniform appearance before they start to develop.

After the class finishes reading page 186, the children may develop on the chalkboard a diagram of the whole life cycle of the salmon. They may write a descriptive phrase next to the name of each stage and may turn ahead to page 194 and identify each stage as pictured there.

Children begin more fully to appreciate the meaning of a life cycle.

Investigation. Ask at an aquarium or pet shop for the kind of water snails that lay eggs. The transparent eggs hatch within two to three weeks. When you transfer the eggs to the dish, take a little plant material with them. Children can make written records and drawings of what they see daily. Begin with a description of the freshly laid eggs.

Equipment and Materials

See text page 187; also the Teacher's Manual for *Classroom Laboratory 4.*

What will the snails look like when they first hatch? They may or may not look like grown snails. We must wait and see. If a child says he is sure he knows, even if it is from past direct observation, let him still suspend judgment. Maybe this kind of snail is different.

Would the snail's eggs hatch in tap water? Transfer a few of the eggs to a dish of tap water, or well water if available. Try the investigation.

You may extend this train of thought by discussing another disadvantage to the salmon if their eggs were laid in the open sea. The eggs would float on the top of the water, an even more hazardous place for defenseless eggs than the bottom of the stream. On the other hand, the smolts can defend themselves, and so they move to the open sea where the food supply is more plentiful than in the stream. This line of reasoning should help make it clear why it is advantageous to the salmon to live its adult life in the sea but to return to the stream to lay its eggs. The migratory habits and life cycle of the salmon are suited to the salmon's special environment.

Equipment and Materials

- . . . overripe banana
- . . . clean bottles
- . . . Moldex (from a biological supply house)
- . . . aquarium with water snails
- . . . ruler
- . . . watch with second hand

Extending the Concept

Observe the life cycle of the fruit fly. An overripe banana in a bottle will attract fruit flies, which lay their eggs on the fruit. The flies are easy to raise and keep. For complete directions see pages 35 ff of *A Sourcebook for Elementary Science.* Use thoroughly clean bottles, and, if possible, add some Moldex to inhibit the growth of mold. The eggs are microscopic, but children can easily see the larva, pupa, and adult stages. Since it takes just two weeks for fruit flies to complete one life cycle, children can observe several generations and see how a life cycle is repeated over and over again.

What are the snail's adaptations? Observe the ways in which the water snail is adapted to its environment. How can a snail stick to the side of the aquarium? How does the snail walk? Using a ruler and a watch, calculate a "snail's pace." Can the snail see? Where are its eyes? Where is the snail's mouth? How do you know? What does a snail do when you touch it? Compare a land snail or a garden slug (a snail without a "house on its back") to a water snail. What differences in its body adapts the land snail to land instead of water?

Reviewing the Concept

(Text page 188)

Before You Go On. 1. b 2. b 3. a

Using What You Know. 1. One-celled animals (protozoans); sponges; the jellyfish's flower-like relatives (sea anenomes); crabs, lobsters (crustaceans); clams, octopuses, and squids (mollusks); many kinds of fish of all sizes. 2. A set of pools graded into steps easy for a fish to jump as it travels upstream. 3. For six weeks it lives on the yolk sac, which disappears as the food in it is used up; now the salmon is a parr, a fish with red spots and stripes; in two years the parr grows into a silvery smolt; the smolt becomes a full-grown salmon in two more years. 4. Eggs, parr, smolt, down to sea, adult salmon, up the river, spawning (or begin with adult salmon).

Section 3: TO THE OCEAN AND BACK

(Text pages 189–95)

SUBCONCEPT

The life cycle of an animal is adapted to the special environment, or habitat.

Processes emphasized

Observation (field trip)
Analysis of observations
Categorizing
Investigation
Hypothesizing
Prediction
Library research

Equipment and Materials

. . . magnifying glass
. . . binoculars
. . . garden tools: spade, pail, etc.
. . . notebook
. . . pencils
. . . collecting bottles

Children understand that in each stage of the salmon's life its structure and activities are adapted to its habitat.

Introducing the Concept

Observe any animal—bird, insect, fish, caterpillar, worm, frog, snake, etc.—at any stage in its life cycle in its natural habitat. This means a class visit to the school lawn, a nearby park, a pond, creek, field, woods, or other area you can walk to. Turn over a rotting log to surprise the creatures living underneath; knock on a hollow tree to rout its possible inhabitants (*Caution:* wasps or bees may inhabit it); dig up a pailful of soil; find an anthill to look at with a magnifying glass; scoop up a jar of pond water; or visit a tree stump to see what is living in it.

Seeing the animal may not be easy, but that is the whole point of this trip! (Do not ignore a conspicuous animal with warning coloration, but try to find another one that has protective coloration.)

After observing animals in nature (or as an alternative introduction), compare the pictures of the salmon on pages 185 and 186 with the pictures on pages 176, 182, and 184. Why are the salmon on pages 185–86 easier to see? Where is it easier to see most animals, in their natural surroundings or in the zoo? Why? (Color, shape, and behavior of many animals camouflage them.) Children may also have observed other adaptive features: size, streamlining, type of feet, type of bill, fins, etc.

How is a salmon adapted for the habitat it lives in? What is the salmon's life cycle?

Developing the Concept

Salmon are adapted to their habitats.

The fitness of salmon. Read page 189 preparatory to the investigation that follows it. Salmon are remarkable for their double adaptation to the salt water of the sea and to the fresh water of their native stream. It is well to recall that grown salmon do not *eat* during the return trip in fresh water, but only while they live in the sea. Thus, adult salmon would die in a pond, for a pond environment does not offer the food supply that the ocean does. (An exception is the landlocked salmon, a different species, which lives in many freshwater lakes.)

Children investigate the structures that adapt a fish for water living.

The investigation. Children will observe that for moving about, swimming, turning, or going up and down, the goldfish uses its muscles, joints, and fins. They will see how fish scales overlap and form a tight, flexible swimsuit. Refer to **The Fitness of Salmon** to confirm responses to the investigation questions. Discuss the likenesses and differences between the adaptations of the goldfish and the salmon. Why are the adult salmon's muscles more powerful than those of the goldfish? Which fish is more streamlined and why? Salmon must swim fast to get food, escape enemies, and make the upstream trip to spawn in time; the goldfish lives a safe life as an ornament in a pool with no enemies and plenty of food.

Children may recall from earlier work that the fish's gills adapt the animal for taking dissolved oxygen from water. They will observe here how water taken into the fish's mouth flows over the gills and out through the gill covers. They may see the red threadlike gill filaments when a gill cover opens. Why are the filaments red? Blood circulates in them and takes oxygen from the water. Cut off the gill covers of a large fish from the fish market. Identify the comblike gill rakers that catch food from the water as it passes through. If you examine the filaments with a hand lens, you may see the tiny blood vessels (capillaries).

Equipment and Materials

. . . fish from market
. . . sharp knife
. . . hand lens

What do fish use their nostrils for if not for breathing? Since no one, not even a fish, can see very far under the water, fish depend much more on their keen sense of smell rather than sight to find food.

Oxygen from water. Reading this subsection will confirm responses to questions on fish respiration arising from the investigation. The importance of dissolved oxygen to fish is made clear in the "armchair" investigation described on page 192, which you may wish to demonstrate if you have time. The oxygen that fish breathe is not the O in H_2O, but molecules of oxygen (O_2), the same as in the air we breathe.

The salmon's life cycle is repeated over and over.

The return. How do scientists know the age of returning fish? How do they follow the ocean travels of fish?

One way scientists trace the journey of the salmon is by banding them. Metal tags with identifying numbers are placed in the tail fins of parr, which later turn into smolts that head down to the sea. Fishermen who catch tagged fish at sea mail in the tags, and thus help to determine the route and duration of the fishes' travels. Ask the children how the use of tags might provide evidence for the theory that salmon return to spawn in the very spot where they were born.

Extending the Concept

Equipment and Materials

- . . . fish skin with large scales
- . . . hand lenses
- . . . goldfish
- . . . tanks of water at different temperatures
- . . . thermometer

Annual rings in fish scales. Another way scientists determine the age of fish is by studying their scales. As a fish grows larger, its skin does not add extra scales, but each of the original scales grows larger. Each scale is made up of rings that resemble the annual rings in the cross section of a tree trunk. Children may study the rings, propose ideas of how they form, do library research to confirm their hypotheses, and decide the age of the fish.

Find a fish's rate of respiration. Count the movements of the open gill cover to see how many times a fish breathes in one minute. Try in water of different temperatures between 30° and 90° Fahrenheit.

Can fish hear? Children can devise their own investigation. They will find that fish do hear very well.

What is the fish's unique sixth sense? Observe the line along the side of a fish. Do library research to learn the use of this "lateral line." (This line is related to guiding the animal through water. Like the fish's keen sense of smell, its lateral line helps make up for the fish's poor eyesight.)

(Text page 195)

Reviewing the Concept

Before You Go On. 1. a 2. b 3. b

Using What You Know. 1. A goldfish lives only in fresh water; a salmon lives in both salt water and fresh water. A goldfish lives in a pond or an aquarium; that is, in calm water. (Goldfish have been bred as ornaments.) A salmon lives in deep, rough oceans and in fast-moving streams. 2. A cow lives on grassy ground and in the farmer's barn; an eagle lives in the air and on treetops. 3. Man lives on the land (with head in the air). The whale lives in the ocean. 4. The salmon has no means of locomotion on ground, has no lungs to breathe air, no way to hunt food on land, and no way to lay eggs out of water.

(Text pages 196–99)

Section 4: SALMON AND WILD DUCK

SUBCONCEPT

Different animals (salmon and duck) are adapted to different special environments.

Children see that the life cycle of a duck, like that of the salmon, is fitted to a special environment.

Introducing the Concept

Equipment and Materials

- . . . pet bird (or chick from local hatchery)
- . . . goldfish

Let a volunteer hold a pet bird (or baby chick) and then touch a goldfish. What are their body temperatures? (The bird is warm to the touch and the fish is cold.) Have you ever felt the water in a rushing stream? What temperature, then, is the salmon egg adapted to? What temperature is the duck egg adapted to? Children are likely to know that ducks, like chickens and other birds, incubate their eggs, sitting on them to keep them warm.

What other differences are there between the adaptations of ducks and salmon? What does migration mean?

Animals are adapted in different ways.

Processes emphasized

Observation
Analysis of observations
Measurement
Investigation (with design of experiment)
Hypothesizing
Theorizing
Prediction
Library research

Equipment and Materials

- . . . two screw-top pint jars with lids
- . . . thermometer
- . . . shoe box of down from an old pillow (or artificial insulation)

The embryonic structures are a special adaptation.

Equipment and Materials

- . . . additional eggs: raw and hard-cooked
- . . . small glass jar or test tube
- . . . thin plastic dry cleaner's bag
- . . . glass funnel

(See also text page 198 and the Teacher's Manual for *Classroom Laboratory 4.*)

Developing the Concept

How does the duck's adaptations differ from the salmon's? Read text pages 196–97. Children should see that the salmon and the duck are alike in that both migrate to lay their eggs but that they are unlike in ways that suit them for different environments.

How is the migration of ducks different from that of salmon? Ducks have a life span of seven to fifteen years. Each year they migrate and lay eggs. Salmon, by contrast, live several years at sea and return to their place of hatching just once to spawn.

Why would duck eggs not survive in the environment that suits the salmon eggs? Which egg "capsule," the salmon's or the duck's, is better equipped for launching the new offspring? Children may mention food storage and parental care before and after hatching. How is this related to the fact that the salmon lays thousands of eggs while the duck lays only a few?

Duck down is the bird's "underwear." Why is a duck's nest lined with down? Fill two jars with warm water. Record the temperature of the water in both. Leave one jar in the open and bury the other one in a box of down (or artificial insulation). Half an hour later, check the water temperatures again. The air layer trapped by the down keeps the covered jar warmer. A down lining is really air-filled insulation for the nest. Why is this an advantage to the duck? (The nest stays warm when the female leaves to feed.)

The investigation. Let the children see for themselves that the membrane and its enclosing shell are porous. Break another raw egg in half. Notice that the membrane clings to the inside of the empty shell. There are, actually, two shell membranes. At the egg's blunt end the two membranes separate, making an air space. Carefully pick away the shell near the blunt end of a hard-cooked egg, and you can clearly see two membranes and the air space. (When a chick hatches, this air space contains crystals of the embryo's wastes.)

Fill half of the uncooked eggshell with water and set it carefully on top of a narrow jar or test tube. Drops of water form at the tip of the shell and drip slowly into the glass vessel. Line a glass funnel with a piece of dry cleaner's thin plastic bag. Pour in water. Is the plastic a porous membrane? Why should this plastic bag be kept from small children?

Explain to the children that an embryo is any young animal during its period of growth before hatching or birth (or, as they will see in Section 6, a young plant in a seed before sprouting). Why must a growing embryo of a bird be enclosed by a porous membrane? Besides air and warmth, eggs need a moist environment. Water vapor can penetrate the shell and membranes and prevent the drying out of the embryo. Which picture on page 185 shows an embryo of salmon? Does the salmon embryo have a porous membrane around it? Children will see that *all* eggs have membranes, even though all do not have shells.

Extending the Concept

The eggs of a hen. Get an undressed hen from the butcher and take out the ovary. It looks like a bunch of grapes with many egg yolks in various stages of development. See how the egg white is added as the yolks pass through the oviduct (tube) and how a shell gland at the lower end of the oviduct adds membranes and shell.

The development of a chick. If you can obtain fertile eggs you may find it rewarding to hatch some chickens. Small automatic incubators are available. Directions for constructing and handling a simple incubator are found on pages 13–14 of *A Sourcebook for Elementary Science.* You may wish to open an egg about every five days, to observe four stages in the development of the embryo.

Equipment and Materials

. . . fertile hen's eggs
. . . incubator

Cold-bloodedness and warm-bloodedness. Fish, amphibians, and reptiles are called cold-blooded because their body temperature varies with the temperature of the environment. We say birds and mammals are warm-blooded, for they maintain a constant body temperature, regardless of the environment. People, of course, are mammals and thus warm-blooded. It is true that body temperatures of cold-blooded animals are lower than those of warm-blooded ones, but this is only part of the story. In the library, find out what cold-blooded and warm-blooded mean to the biologist. How does cold-bloodedness or warm-bloodedness adapt an animal to its environment?

Animals to touch

. . . pet bird or baby chick from local hatchery
. . . goldfish
. . . frog, garter snake, dog, cat, hamster, etc.

Reviewing the Concept

(Text page 199)

Using What You Know. 1. In the new environment, (a) the dinosaurs were not fitted for getting enough food to live long enough to reproduce, or (b) their eggs were not well protected from new enemies. (An answer that focuses on the key stage of reproduction is best, but other good responses to the question may be made as well.) 2. The duck has a lightweight body and strong wings and can "retract its landing gear" (tuck up its feet) for streamlining. (Also eats enormous amounts of food that furnish a large-enough supply of energy for flying.) 3. It has feathers to spread over nest as it sits on eggs to keep them warm; it builds down into the nest for insulation (warmth). The female has protective coloration that hides nest from enemies. 4. The shell and membrane are porous to allow air in; the egg is full of stored food for the embryo to grow on.

Section 5: THE LIFE CYCLE OF A DUCK

(Text pages 199–202)

SUBCONCEPT

In both structure and behavior (migration) the duck is adapted to its environment.

Children learn the particular ways in which ducks are fitted to their environment at different stages of their life cycle.

Introducing the Concept

Display a baby duckling or chick, either the real thing or a large picture of any baby bird. A child may lend a pet for the occasion. Or you may get a chick from a hatchery. How will this young creature change

Equipment and Materials

- . . . baby duck or chick
- . . . large picture of duckling, chick, or baby bird

as it turns into an adult? It will grow larger; its feathers will change in texture and color; its body proportions will change—at present its head and feet are too big; and so on. Now look at the pictures on pages 198 and 199. What happens inside the egg that turns the embryo into the just hatched bird? The embryo uses up the food in the white and yolk as it grows into a duckling. From now on, what does the duckling do to turn into an adult? (It eats.)

What is a wild duck's life cycle?

Developing the Concept

An organism needs food for growth.

Equipment and Materials

- . . . sand
- . . . scales

From duckling to adult. Read as far as **The Long Journey** (page 200). A duckling weighs only a quarter of an ounce when it hatches. Within eight weeks the young duck can fly, and within a few months it will weigh about 3 pounds (48 ounces). Weigh out a quarter-ounce pile of sand and place it beside a 3-pound pile of sand. To gain so much in such a short time, a duckling must really eat like a glutton!

Wild mallard ducks are adapted to an annual cycle of migration.

Equipment and Materials

- . . . large topographical map of United States and Canada
- . . . thumbtacks
- . . . string

Processes emphasized

Measurement (mapping)
Observation (field trips)
Analysis of observations
Library research
Consulting experts

Migration. The routes taken by migrating birds are known as flyways. After reading **The Long Journey,** you can use a topographic map of the United States and Canada to show the children a 2,000-mile journey taken by migrating mallards. Tack one end of a string to the mouth of the Mackenzie River in Canada. With the other end of the string reach the delta of the Mississippi. Why is this a fine flyway? (No elevation over 2,000 feet.) With other strings, let children trace the Atlantic flyway from Canada and the Maritime provinces through the main river valleys of the Northeast down into Florida. Trace the Pacific flyway from Alaska down the coast into Central America. From Alaska and the Canadian Northwest territory trace the southeastern flyways along the base of the Rockies to the delta of the Colorado River. (Many mallards have been domesticated and stay in one location the year long; other kinds of ducks, sometimes called mallards, have different adaptations.)

One of the many uses of a bird-feeding station is to observe the migratory habits of birds in your area. As a year-long project children can keep detailed records of the birds seen at the feeding station and come to their own conclusions about which ones migrate, and when. *Living Things* (pages 28–29), one of the NSTA series *Investigating Science with Children,* gives instructions for building two types of simple bird feeders, one for the classroom window and one for the school yard.

Children appreciate that scientists continually seek evidence.

How do they know? If asked why birds migrate, children may suggest that the birds feel winter coming and want to go where they will keep warm. It may be hard for children to overcome this mistaken belief. Like many other commonly held ideas about animal behavior, it is based upon false analogies with human behavior. (Another example: Squirrels store nuts because they know winter is coming.) You may try, then, questioning the children about the return trip of migrating birds. Why do the swallows that nest about the California mission at San Juan Capistrano return on or near the same date nearly every year? Other birds are not so precisely punctual, but in any area a bird calendar can be made telling about when to expect the red-winged blackbirds, the robins, the tanagers, the warblers, etc., to return in the spring. How do the birds know when it is spring "back home"? (It is not expected that children can answer this!) If a child anticipates the next section and tries to answer the "how do they know" questions, counter him with "how do *you* know?"

Extending the Concept

Migration of other animals. What animals migrate besides salmon, ducks, and other birds? Do a library investigation on the migration of seals, butterflies, elk, or lemmings.

Conservation. Do library research on migratory bird laws, wildlife refuges, and feeding stations. Is there a bird sanctuary in your city? What is meant by sanctuary? (Illegal to shoot birds there.)

Use a resource person. The local Audubon Society may send someone to explain conservation of birds, to help children identify birds, and to show how birds are banded to study their migration habits.

Reviewing the Concept

(Text page 202)

Before You Go On. 1. b 2. a 3. b

Using What You Know. 1. A young duck must be kept warm and protected by its mother. She also helps it to hide from enemies. If you take into account the parental care, the young duck is completely adapted. 2. The young salmon lives for six weeks on the food in its yolk sac which it brought with it from the egg; a young duck begins to feed itself as soon as it hatches. A young salmon must fend for itself; a young duck has parental care.

Section 6: KNOWING HOW TO BEHAVE

(Text pages 202–08)

SUBCONCEPT

All organisms have inborn behavior that adapts them to their environment.

Processes emphasized

Observation
Analysis of observations
Investigation
Hypothesizing
Prediction

Equipment and Materials

. . . potted plant in window (left for several days without turning)
. . . any living animal

Children recognize that organisms have inborn ways of responding to stimuli that help fit them to their environment.

Introducing the Concept

What is the first word that comes into your head when I say "behave"? Many children will answer "yourself." When I say "behavior"? All too often, the answer is likely to be "good" or "bad." Explain that the scientist's meaning of "behavior" expresses neither approval nor disapproval. Look at the animal in this cage (or fish in this jar, or kitten in my hand). What are some examples of its behavior? (It moves, eats, cries, etc.) Look at the plant in the window. Does it have any behavior? (Turns its leaves toward light.) A brief discussion of several examples of this kind will help children understand that the behavior of a living thing is everything it does. The life cycles of the salmon and the duck describe the behavior of these animals.

How do we know how salmon and ducks behave as they do? How do we know about a plant's behavior? How do we know about our own?

Developing the Concept

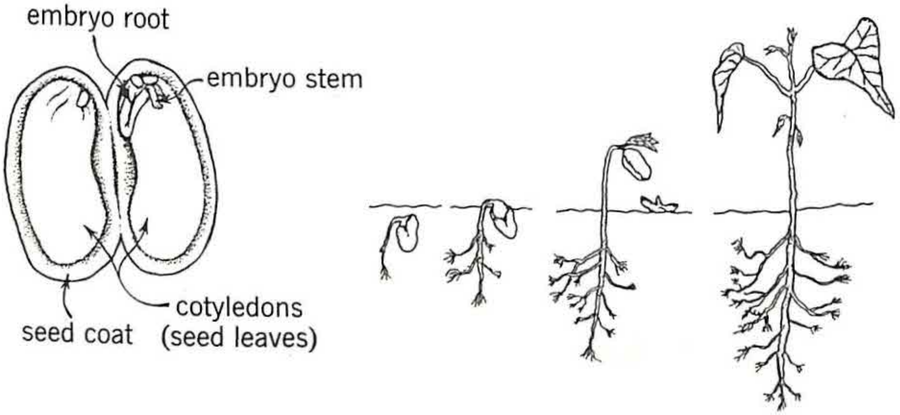
Plants have life cycles adapted to growth in their environments.

Equipment and Materials

. . . lima bean seeds (extra supply)
. . . paring knives
. . . hand lenses

(See also the Teacher's Manual for *Classroom Laboratory 4.*)

The investigation. As soon as the opening of the section has been read (page 202), start the investigation. Use packets of bean seeds sold for planting rather than for eating. Let the children examine and describe the seeds before and after soaking. Soak extra seeds so that children can see the contents of a seed before it begins to sprout. Ask them to remove the seed coat and carefully separate the two halves of the bean. These halves may be called "seed leaves." The botanist's name for them is *cotyledons*. Attached to one seed leaf is the tiny embryo root and embryo stem (see the figure). To what part of a bird's egg may the seed leaves (cotyledons) be compared? (Yolk and white.) Why? (Both contain stored food for the embryo.)[°]



You may find it helpful to place each bean or corn seed in a hole cut in the blotter to hold it in position. When the children watch their own seeds sprout, they can easily interpret the results in the photographs. Notice (see figure) that only the main root, the one already present in the seed, grows downward. The side branches grow later.

Behavior may be inborn or learned.

When? As children read pages 206–07, they are probably aware that some of their own behavior is learned and some inborn. They can see that many of their automatic responses are learned. When they answer "four" to "What is 2 plus 2?" they know this is a learned response. A few responses are inborn reflexes as they can see for themselves.

Equipment and Materials

. . . ruler
. . . lemon
. . . knife
. . . spoon
. . . medicine dropper

Why does Johnny's knee jerk when I tap it like this? Ask for a volunteer to sit on a high stool or on top of your desk, cross one leg over the other, and let the crossed leg hang relaxed. Tap just below his knee with the blunt edge of a ruler. What is the stimulus? (The pressure of the ruler.) The response? (The movement of muscles in the leg.)

[°] Strictly speaking, the cotyledons are *part* of the embryo. This confusing botanical fact is perhaps best left unsaid.

Why does your mouth water when you taste (or perhaps even smell) a drop of lemon juice? Cut open a lemon and squeeze some juice into a spoon. Place a drop of juice on a volunteer's tongue. What is the stimulus? (Substance in juice.) The response? (Salivation.) Children in the class will often salivate in response to the odor alone, but this is a response learned very early in life. Only the response to taste is inborn.

Scientists have proposed several hypotheses to explain the migration of salmon. Among these is that the animals' extremely keen sense of smell enables them to find their way back by the odors of their home waters. Another is that the salmon orient themselves by the sun, with a kind of "sun-compass" mechanism.

In the duck and other migrating birds the increasing number of hours of daylight in the spring may serve as a stimulus to the maturing of the reproductive organs. Since the laying of eggs and rearing of young is the main occupation of the birds' northern spring and summer, a causal connection between reproduction and migration seems reasonable, but this has not yet been proved. Be sure to point out that we only know that migration is inborn and somehow influenced by the cycle of seasons.

Extending the Concept

Do roots grow or turn toward gravity? How do we know the roots grow down and do not simply turn down? Make a "sandwich" garden. Place a piece of wet blotting paper on a small glass square. "Plant" several soaked radish or mustard seeds on the paper. Place another square of glass on top and tie the sandwich together with a string. Set on edge in a shallow dish of water. When roots have begun to grow, turn the sandwich 90 degrees. What happens to the roots as they continue to grow? (The part of the roots that has already grown does not change position, but new growth is straight down.)

Equipment and Materials

. . . two glass squares
. . . blotting paper
. . . radish or mustard seeds
. . . string
. . . shallow dish

Stimulus-response mechanism. Use a feather or light touch to tickle the hind toe pads of your sleeping cat or dog. How does the animal respond? Observe your pet and make two lists of behavior, one list showing which reactions you think are inborn and the other, which are learned. One way you may check your lists is to compare them with those made by other members of the class. Why? (If my dog responds differently from your dog to the same stimulus, the behavior is learned.)

Reviewing the Concept

(Text pages 207–08)

Before You Go On. 1. b 2. b 3. a

Using What You Know. 1. We expect the stems of plants to grow away from the earth. This is just the opposite of the inborn behavior of roots, which grow towards the earth. 2. Birds separated from their parents since birth still make the same kinds of nests that the parents made. 3. Yes. (Blinking, yawning, knee jerk, breathing, heartbeat, etc.) A baby is capable of all these acts from the moment of birth and does not have to learn them.

(*Text pages 208–13*)

CONCEPTUAL SCHEME

A living thing is the product of its heredity and environment.

UNIT CONCEPT

A living thing reproduces itself and develops in a given environment.

Section 7: The MAIN CONCEPT: ADAPTATION TO ENVIRONMENT

Children form a concept of the fitness of each kind of living thing in its structure and behavior for its particular environment.

CONCEPT SUMMARY

To the "strange" stories, now familiar, of migration in salmon and ducks could be added countless descriptions of adaptive structure and behavior in animals. A single cocoon hatches into hundreds of tiny praying mantises; a rabbit turns in its summer coat of brown for a winter white one; a blind bat uses its own radar to navigate a lightless cave. One of the most common and natural interests of children is collecting such animal lore, both by direct observation and in their reading. Hence, they have a fund of information for the concepts developed in this unit.

The children have been asked to step back a little way from their usual close view of a living thing as an isolated object and see it in relation to its surroundings. However simple or complex, familiar or strange, each part of an animal's body and everything the animal does may be seen as part of its fitness for survival in its own natural setting, its habitat.

How do we get direct evidence?

Direct observation. As he reads **The Main Concept,** let each child ask himself, "How do *you* know?" How, for instance, do you know that a fish's body fits it for life in the water? that a hen's egg is suited for the growth of an embryo within? that the root of a bean grows toward the Earth? If children have been able to carry out some of the classroom and outdoor investigations of this unit, they can respond "We could see for ourselves." They have direct evidence to support their concept of the fitness of a living thing for its environment.

You may wish to perform additional investigations involving direct observations. Earthworms are interesting to study. You may get them from a fish bait dealer, or the children may collect the worms from sidewalks or soil after a spring rain. Why do the worms appear when it rains? (Rain fills the worm's burrow and forces it out to get air.) Place a worm in a box of slightly moist soil. Let the children make hypotheses about the worm's behavior, as it promptly digs into the soil. Is the worm responding to moisture, air, soil (as opposed to sawdust or wads of cotton), light, touch, temperature? Children may devise investigations to test their ideas. Observe how the worm is equipped for crawling, digging, feeding. (What does it eat?)

How useful is indirect evidence?

Indirect evidence. How do you know that salmon return to their native streams to spawn? That mallards may fly 2,000 miles to their winter homes in the south? That junco birds respond to the length of daylight? Children know many facts and ideas about adaptive behavior through their reading and discussion. This material is the indirect evidence upon which children build their concepts. We depend on scientists with various special interests to furnish us with such evidence.

What is a "biological clock"?

Children will be interested in reading or hearing about the findings of investigators into "biological clocks" in both plants and animals. Organisms of many kinds have inborn internal mechanisms that seem to be "set" by environmental factors such as time of day, length of daylight, and temperature. Behavior that recurs at daily, annual, or seasonal intervals seems to be governed by such clocks. Children will recognize the idea in what they know of the inborn behavior of migrating animals.

Do both plants and animals adapt to seasons?

Some insects resemble annual plants. Both die in the fall and leave offspring which spend the winter in a well-protected and inactive state—in cocoons or seeds. Biological clocks seem to be at work in both.

What are some other seasonal adaptations of animals? Children may do a library investigation of hibernation in mammals. What is meant by true hibernation? Among the few mammals that go into true hibernation are hedgehogs, hamsters, some bats, and woodchucks. (Bears and some other mammals sleep in the winter but not in true hibernation.)

How much of an organism's behavior is inborn? How much is learned?

Inborn or learned? Mention pet mice or parakeets, cows on a dairy farm, or tigers in the circus ring, and it is immediately plain that many animals can learn. Children know that some animals are capable of a much higher degree of training than others. Can *all* animals learn? What about protozoa and earthworms? The evidence is that even these lowly creatures have some capacity to modify their inborn responses.

It is largely because we know fish and birds *can* learn that scientists have to do careful research to determine whether they *do* learn such things as migration behavior. In discussing how the scientists know what they do know (which is far from enough to satisfy their curiosity on the subject) about migration, you may wish to mention the recent use of tiny radio transmitters sewn (painlessly) into the fins of fish to aid in tracking them. What are the advantages of this over the older methods of tagging fish and banding birds?

What is the total environment?

Living things in the environment of living things. What would a salmon do without smaller fish to eat? What would a duck do without twigs to build its nest or grass to help hide it? If you subtract other living things from the environment of living things, what's left is hardly inhabitable. You may wish to close the unit with a discussion of the interrelationships between living things and their environment.

Ask the children if anything could live on the Moon. What needs of living things (as we know them) are not present in the Moon's environment? If they think first of needs of green plants, children may list air, water, certain soil minerals, light, and moderate temperatures. Then, from their work in earlier units and their knowledge of food chains, children know they have listed the basic needs of animals and nongreen plants as well. The evidence is that at least some of the conditions are certainly not present on the Moon, but children should check recent findings. (No one expects to find any air on the Moon, but it is just possible that water may be found under the Moon's surface.)

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On Earth, of course, the basic needs of plants in the nonliving environment are present. For their energy supply, green plants do not need other living things. But when we consider the role of decay bacteria in recycling materials needed by green plants, even the green plants seem to depend on other living things. Scientists believe that the nongreen plants are descended from green ones that lost their food-making function and took up the role of decomposers. Thus, the nongreen plants became necessary links for the survival of future generations of green plants. The adaptations of any living thing—green plant, nongreen plant, or animal—to its environment involves other living things. In its statement that living things are "part of the life and land and water about them," the unit closes with a reminder of its early concept of food chains and a restatement of its central concept of adaptation to environment.

(*Text pages 210–13*)

FIXING THE MAIN CONCEPTS

Testing Yourself. **1.** a **2.** b **3.** b **4.** a **5.** a **6.** a **7.** b **8.** a **9.** a

(*Text pages 214–17*)

A NEW VIEW OF LIVING THINGS

CONCEPT RELATIONSHIPS

The inherited characteristics of a living thing can develop only in the kind of environment in which the growing plant or animal can interchange matter and energy with the environment.

The children have been studying two conceptual schemes: A living thing is a product of its heredity and environment, and living things are interdependent with one another and their environment. Here they see that these two major concepts are related. During the entire life cycle of a plant or animal type, the conditions of the environment must be favorable to development, and the matter, whether living or nonliving, from which energy is derived must be adequate. Living things are adapted to the total environment.

TEACHING SUGGESTIONS

Seeds transmit the characteristics of the parent plants.

Equipment and Materials

. . . unfamiliar seed types
. . . hand lens

Seeds. You might want to introduce this New View in this way. Bring to class some seeds of a kind that the children are not likely to recognize. (If you are teaching in a town or city, this won't be difficult, but if your children come from a farming community you may have to do some research!) Nasturtium seeds, for instance, may be about the size of the eraser on the end of a pencil, and look rather like tiny cashew nuts. Marigold seeds are curved slivers about a quarter of an inch long and two-toned. Beet seeds are bur-like, the size of a kitchen match head.

Give a seed to each child. If hand lenses are available, let them be used to examine the object, which you have not identified at all, of course. What is it? When it has been identified as a seed, with or without your help, you may want to ask what kind of seed it is. This is obviously an unfair question for many classes—but it may allow you to develop the point that the seed has to be some one kind of seed; it can grow into one kind of plant only. Why does the seed develop into just one kind of plant? Because it has within it the characteristics of just one kind of plant. Where did the seed obtain these characteristics? From the parent plant. Parents pass on the characteristics of the living thing to their young.

If . . . Is this seed alive? Presumably it is, barring accidents. How can we find out if it is alive? By planting it and seeing if it will grow. Why isn't the seed growing now? Because the seed needs certain things to grow and certain conditions; the key word here is *environment*. This seed, this living thing, must have a *special environment* to develop. In other words, it is *adapted* to a special environment. Now, to confirm the use of these terms, and to broaden the concept to include living things in general, turn to **A New View of Living Things,** text page 214, and read as far as **A Part of the Environment.** You may perhaps dwell for a while on the idea that differences in environment affect growth and development of children as well as other living things by asking what differences in environment can affect a child's growth. Incidentally, the package in which seeds are sold often includes a description of the environment the seeds require for their growth.

A living thing is adapted to a special environment.

Changing environment. When the children have finished reading this short section, they may be asked if the seed they have been examining is adapted to more than one environment. They may be able to point out that the seed is adapted to staying alive in the environment of the package in which it was sold. In an environment without food, water, or sunlight, the seed does not grow or develop; but it is adapted to staying alive until it is given the right special environment. In what environment will the seed not germinate? You may find that the instructions on the seed package are explicit about frost, for example.

A living thing may be adapted to different environments.

A part of the environment. The seed that the children have been examining requires a special environment to grow and develop. Is it part of the environment that some other living thing requires to grow? It should not be difficult to discover some living things that make use of the plants that grow from the seeds, as food or as shelter. What of the seeds themselves? Are they food for some living things? And the living things that make use of these plants—are they a necessary part of the environment of some other living things? The concept of interrelated environments and living things can be extended in this way. What of the children themselves? They depend on their environment, certainly. Are they part of the environment for other living things? They are indeed. They too are included in the concept that living things are not only dependent on their environment but are part of it.

Living things are a part of the environment.

What does this suggest, then, about making changes in our environment? It should suggest that changes be considered carefully before they are made, for a change in one part of the environment may affect other parts and affect other living things.

UNIT SIX

THE JOURNEYS OF A SALMON AND A DUCK

Do you know what these are?

These are the eggs of a fish—a salmon.
They lie at the bottom of a river in Oregon.

These eggs are the beginning of a strange life and a long journey. It is a journey which will take the young salmon thousands of miles away, and back here again.

Where do the salmon go? Why do they come back?

Let us find out.

1. In the Spring

The water in a river in Oregon is still very cold in the spring. It still has the feel of ice and snow from the winter that has just passed. It is hard to imagine that anything could live in that cold water.

Yet down on the bottom of the river, if you could explore there, you would find life beginning and thriving. In among the rocks and gravel on the river bottom, you would see these tiny creatures darting about. ■ If you explored still further, you would find some hatching from eggs like these. ● At first they live on a food supply in the yolk sac. Later they feed on tiny plants and animals.

■

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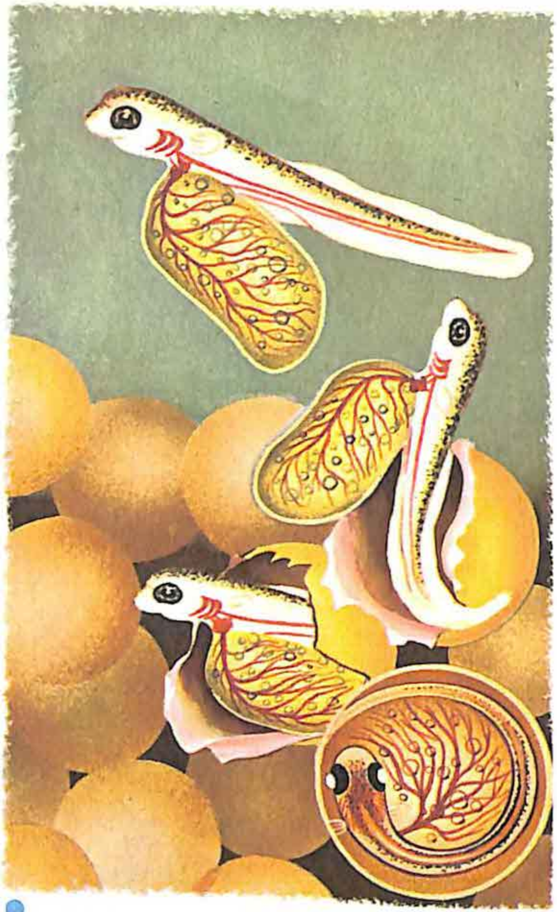


What are these creatures that can live and thrive in such surroundings? They are young salmon. How their eggs come to be in a cold river in Oregon is a strange story. Let us begin it by looking at the food that these young salmon find about them. This is something that you can see for yourself, in the investigation on the opposite page.

AN INVESTIGATION into a Food Supply

Needed: a stream, a pond, or an aquarium; a piece of hard-boiled egg yolk or some rice, four jars, four labels, a good hand lens or a microscope

Do this investigation in the spring, when the trees are beginning to show leaves. Scoop up a jar of clear water from a stream or pond, or from an aquarium. In a second jar scoop up water and some of the mud or gravel from the bottom.

Back in the classroom, pour half the contents of each jar into two other jars. Now you have four jars, two with clear water and two with water and mud or gravel.

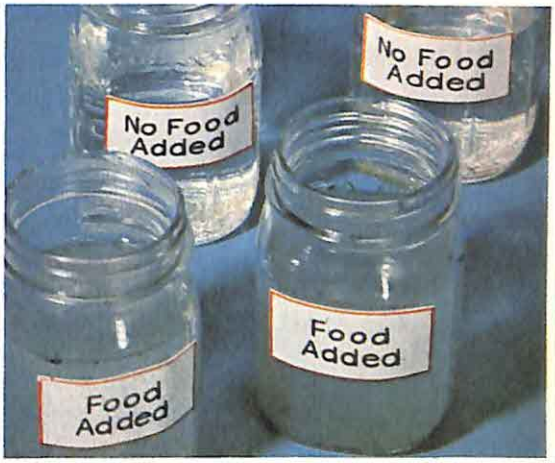
Take a jar of clear water and a jar of mud or gravel and label them "Food added." Label the other two jars "No food added."

Into the jars labeled "Food added" put five grains of rice or a bit of hard-boiled egg yolk about the size of a pea. Crumble the egg yolk as it is added to the water. Put no egg yolk or rice in the jars labeled "No food added."

Keep all the jars in the classroom, but away from heat and direct sunlight. Examine them every day. In a few days the jars to which food has been added will become cloudy.■ Are the other jars cloudy?

Pour some of this cloudy water into a test tube and examine it with the hand lens.● The specks swimming about are tiny animals. They are living on the food you added to the water.

Tiny animals like these are a part of the food supply for many young fish.



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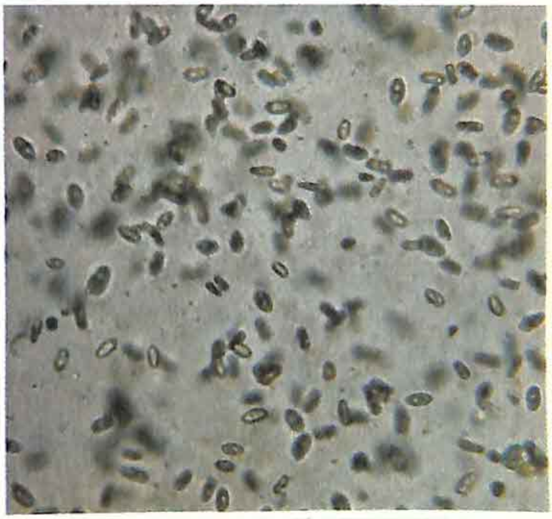

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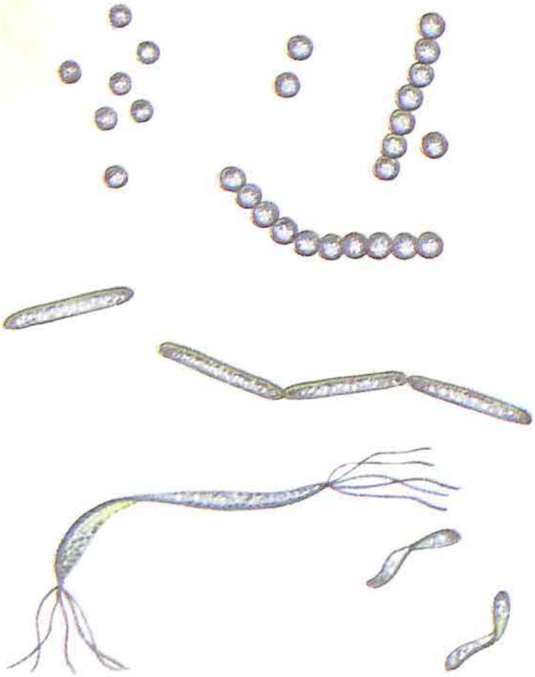
Food for Young Salmon

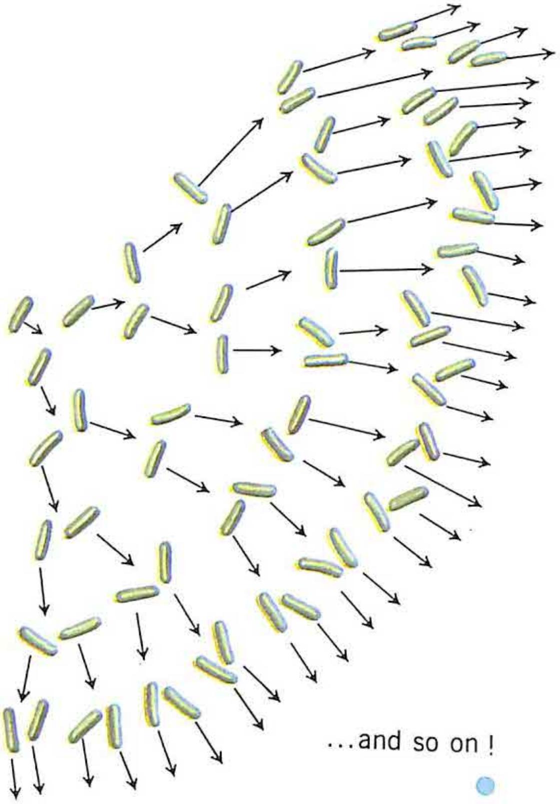
A jar of clear pond water seems to have no life in it. Then food is added to the water and life appears, tiny specks of animals moving about. How does this happen?

When egg yolk (or rice) is added to the water, you can see a change take place in the yolk from day to day. We say the yolk decays. The change takes place because tiny living things in the water are feeding on the yolk. These living things are very tiny plants called bacteria, as you will recall from your earlier work.

Bacteria are so small that they can be seen only with a good microscope.

■





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To your eye the pond water may seem clear. Here are some bacteria in pond water, as seen under the microscope. ■ Bacteria are so small that about 100,000 of them would fit into the period at the end of this sentence.

The bacteria feed on the egg yolk and the yolk decays. As the bacteria feed, they make more of themselves. One splits into two. Two bacteria become four. Four bacteria become eight. Eight become sixteen, and so on. ● In a few days the clear water in the jar becomes cloudy, because of the millions upon millions of bacteria living in the water.

There are other living creatures in that clear pond water, though, besides bacteria. There are tiny single-celled green plants called **algae** (AL-jee). Algae are much larger than bacteria, but some types are still too small to be seen. There are also other tiny single-celled animals, called **protozoans** (proh·teh·ZOH·enz). Here are some protozoans.▲

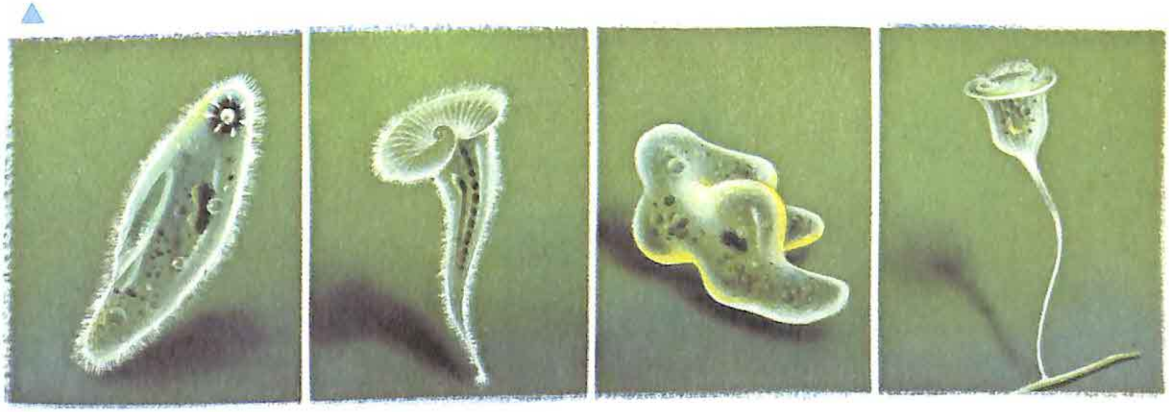
The slipper-shaped protozoan that is first in line is called a *paramecium* (par·ah-MEE·shee·uhm). A paramecium is much larger than one of the bacteria. One hundred thousand bacteria of decay could fit into the period at the end of this sentence. Only five paramecia (the pural of *paramecium*) could fit there.

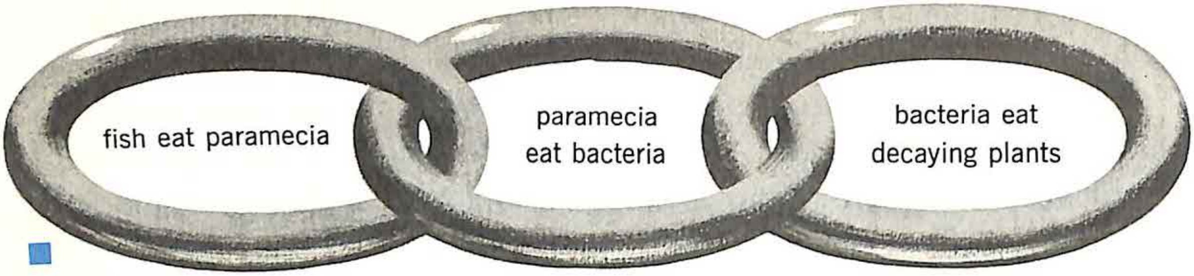
The paramecia feed on the bacteria. If there are plenty of bacteria, the paramecia make more of themselves. Each paramecium splits to make two paramecia. Those two split to make four paramecia, and so on. In a few days the jar of pond water is swarming with paramecia. The moving specks that can be seen with the hand lens are paramecia. There are also plenty of other tiny animals that you cannot see.

In your jar of pond water, the bacteria fed on egg yolk or rice. Then the paramecia fed on the bacteria. So did the other tiny animals.

Now let us go back to that river in Oregon. It is spring, and the salmon eggs on the bottom of the river are hatching. The young fish are wriggling out of the eggs. They begin to feed. What are they eating? The tiny life—the algae, protozoans, and other tiny plant and animal life—are their food. The young fish are snapping up protozoans, other tiny animals, and algae. The protozoans

▲





and other tiny animals are feeding on the bacteria in the water. The bacteria are feeding on bits of plants in the water. This is called a **food chain.** ■

The young salmon was born in the right surroundings, wasn't it? At least it had a supply of food. Those salmon eggs were laid in the right place. The salmon that laid those eggs made a remarkable journey to lay them in just the right place. It was a long, long journey, and a dangerous one. Let us follow, in the next section you will study, a salmon on the journey to the right place to lay its eggs.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Paramecia produce other paramecia by
   a. hatching from eggs
   b. dividing
2. The young salmon feeds not only on tiny animals but on tiny plants known as
   a. algae
   b. protozoans
3. A young salmon is
   a. part of a food chain
   b. not part of a food chain

USING WHAT YOU KNOW

1. Suppose that a paramecium can divide into two paramecia every 20 minutes. How many paramecia will there be in 2 hours?

2. Hawks eat snakes. Snakes feed on mice. Mice feed on grain. Draw the food chain.

3. Draw the food chain that begins with a decaying plant and ends with a young salmon.

ON YOUR OWN Draw a food chain with *you* in it.

2. The Great Journey Begins

The Pacific Ocean is vast. It washes against our west coast from northern Alaska to southern California.● From our coast it stretches thousands of miles to the west. In the Pacific Ocean are enormous numbers of living creatures, of many different kinds. There are the simplest animals, made up of just one cell. There are animals made up of many cells: sponges, worms, and relatives of the jellyfish, some that look like beautiful flowers. There are also crabs and lobsters of many kinds, and clams and other animals with shells. (One clamlike animal is the size of a small child.) There are octopuses and squids.

Then there are the fish. There are thousands of kinds of fish in the Pacific Ocean. Among them are the salmon.

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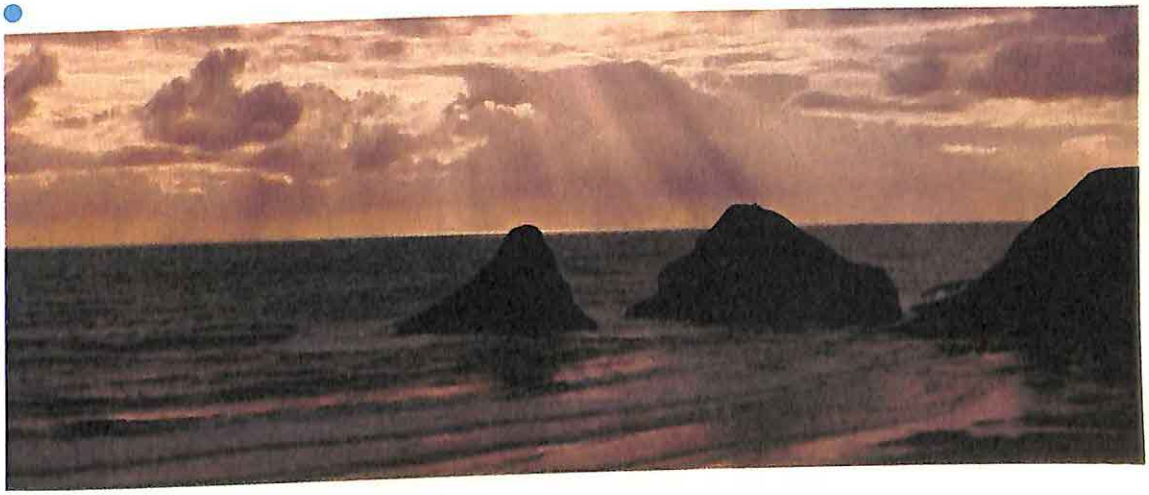
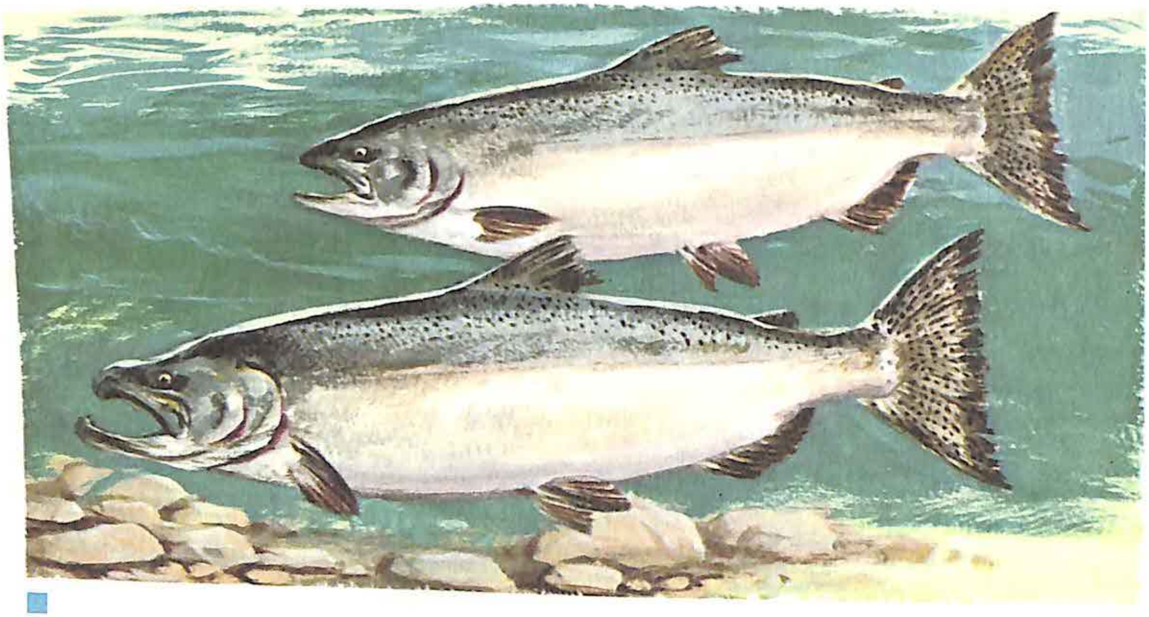




■

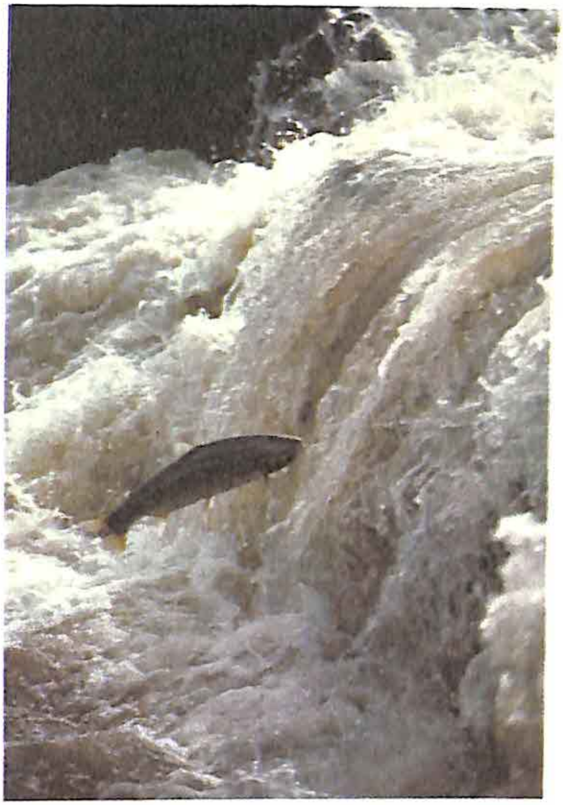
Here are two full-grown Chinook salmon, a male and a female, about 4 years old. ■ Each weighs about 25 pounds and is nearly three feet long. The female salmon is ready to lay her eggs. She will not lay them in the Pacific Ocean, however. Where will she go?

When it is almost time to lay the eggs, both salmon begin a great journey. They begin to swim toward the land. Thousands of salmon in the Pacific Ocean do the same. Each salmon is heading for the river where it was born. Not only that, each salmon is heading for the very part of the river where it was hatched. A salmon may be a thousand miles from where it began life, yet it always heads for that place.

As the salmon swim, larger fish attack them. The salmon are food for some other fish. The salmon swim on. Some are caught by fishermen. The salmon that are left keep swimming. Their goal is far up the rivers that empty into the Pacific Ocean. As they swim, each salmon loses weight, because it feeds less and less.

What do the salmon do when they find a waterfall in their way? They leap up the waterfall, if it is not too high. Salmon can leap up a fall as high as ten feet. ● They leap by swimming at full speed under water, then rising to the surface. In some places the men of the United States Fish and Wildlife Service come to the aid of the salmon. Where the salmon cannot leap the falls, men have built **fish ladders.**▲ A fish ladder is a kind of stairs for fish to climb. The fish leap from one step to the next higher one. The fish ladder in the photograph allows the salmon to climb quite a height and reach the stream above the falls.

At a certain time in its life cycle, a salmon is adapted to life in a stream. At another time, it is adapted to life in the sea. The salmon behaves differently at different times of its life. The way it behaves is part of its adaptation to its environment.



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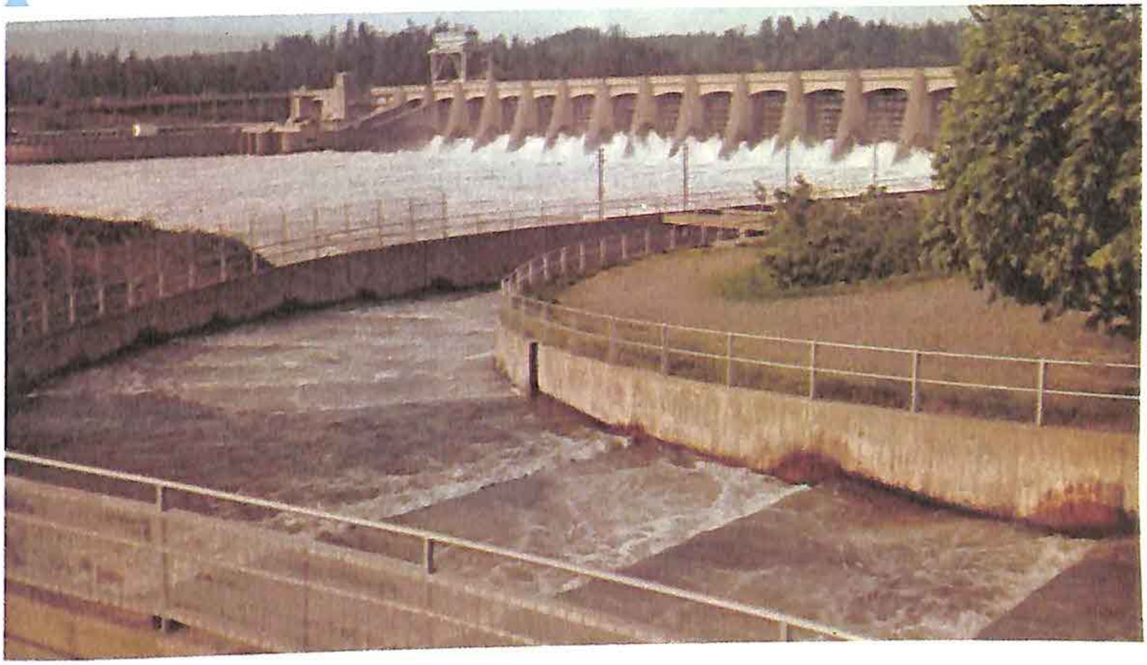

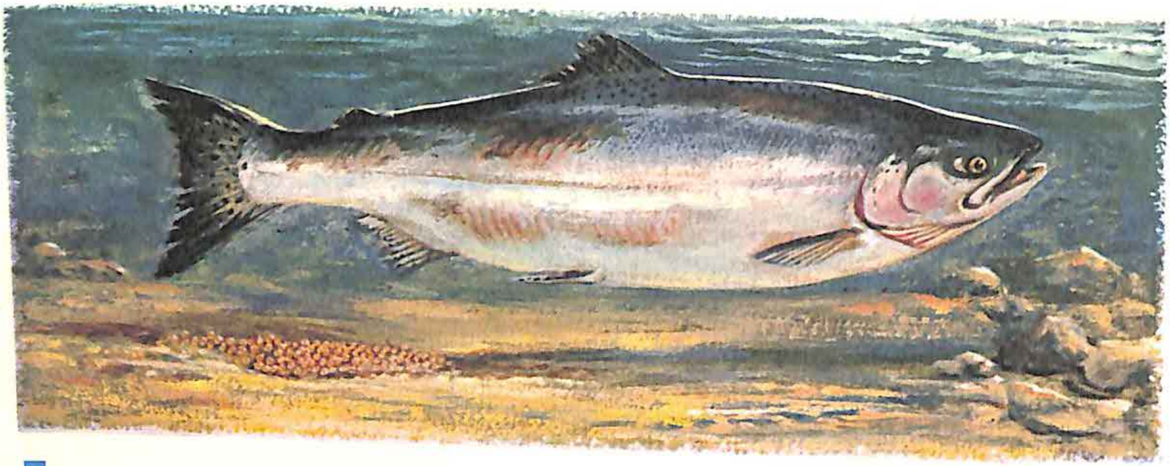

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At last the salmon that are left, at the end of this great journey, reach the places where they were hatched, far up the rivers. Some reach there in summer, others in the early autumn. They have come hundreds, even thousands of miles, and it has taken them weeks and months. They have survived many dangers. Here the salmon **spawn.** That is, the female salmon lays **eggs,** and the male salmon lays **sperm** over the eggs. For there to be young salmon, both eggs and sperm are needed. The place where the salmon do this is called their spawning ground.

At the spawning ground the female salmon lays from 8,000 to 10,000 eggs. Are these eggs just laid on the bottom of the stream? No, the salmon make a kind of nest. Before the eggs are laid, both salmon move along one place on the bottom, moving their heads and tails from side to side. They make a long hollow in the river bed. There the female lays the eggs. ■ The eggs fall between the stones in the hollow. There they lie, protected by the stones, until they hatch.

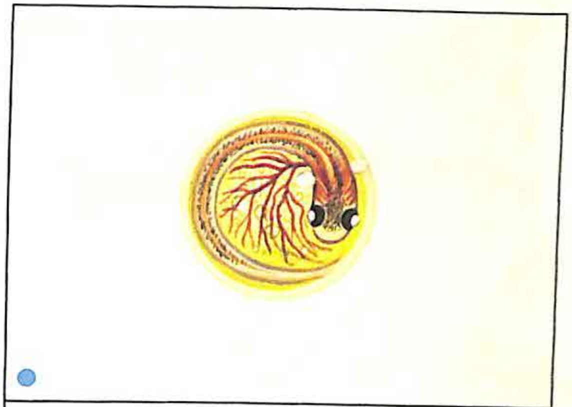
This is the end of the journey for the old salmon. For the young in the eggs, it is the beginning.

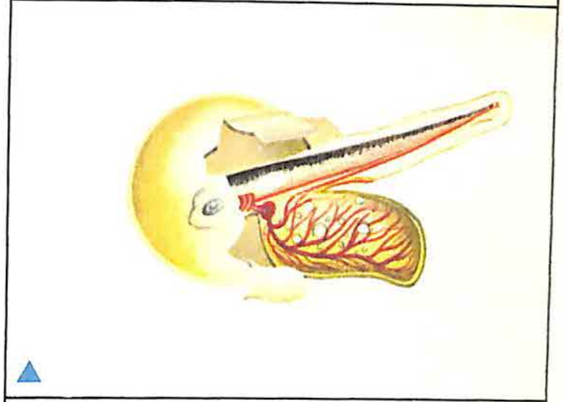
The Young Salmon and Their Journey

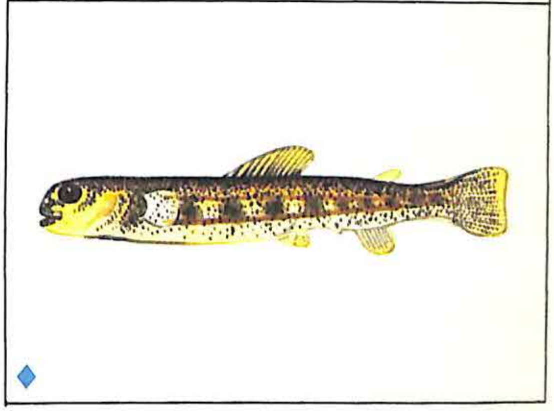
You may have seen a guppy give birth to young fish. (The guppy is a fish you often see in home aquariums.) The male guppy is brightly colored. The female is olive colored. The female guppy does not lay eggs, as most fish do. The eggs hatch inside the guppy. Then, when the young fish are born, they are ready to swim about.

How different the salmon is from the guppy! The guppy does not lay eggs; the young are born from the female guppy. The salmon lays its eggs in a stony hollow. The eggs fall between the stones, so most of the eggs are protected. They are protected from other fish, that is; for salmon eggs are good food to other fish. There, among the stones, the eggs lie for a while. Nothing seems to be happening to the eggs.

What happens in a salmon egg while it is lying between the stones at the bottom of a river?





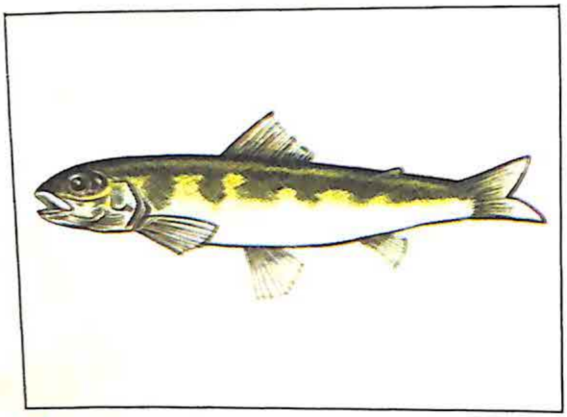


How a Salmon Egg Hatches

When a salmon egg drops between stones at the bottom of a river, the young salmon is already growing inside the egg. This happens in late fall. When the young salmon inside the egg reaches this size, it stops growing. ● It remains in the egg, not growing at all, during the winter.

Then in early spring the young salmon begins to grow again. It forms a yolk sac. Now it is ready to hatch. The young salmon, yolk sac and all, bursts out of the egg. ▲

This very young salmon is less than an inch long. It carries its food in the yolk sac, and lives on the yolk for about 6 weeks. By the time that the yolk is used up, the young salmon looks like this. ◆ Now it looks more like a fish, doesn't it? But with those spots and stripes, it does not look like a salmon. (In fact, people



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used to think that it wasn't a salmon.) The young salmon is now called a parr.

The parr is fast and it has good teeth. It feeds on water insects and other small animals in the river. In 2 years it grows to be almost 8 inches long, if no enemies have caught up with it. No longer does it have red spots and stripes. The young salmon has a shiny, silvery coat. ■ Now the young salmon, two years old, is called a smolt.

Now that it is a smolt, the young fish is ready to go on a journey, a long journey to the ocean. It heads down the river. It reaches the mouth of the river, where the river water flows into the sea. The smolt heads out into the Pacific Ocean. There it lives for 2 years and becomes a full-grown salmon. In the Pacific it hunts for food and fights to protect itself. It is on guard against its enemies, and ranges for hundreds of miles through the ocean depths. The salmon can do all these things because it is equipped to do them.

The adult male and female salmon came from the sea to the river. There they spawned. The young hatched from the eggs. The young grew and became smolts. The smolts headed for the sea and became adults.

This is the life cycle of the salmon. It is called a cycle because the life of the salmon is repeated over and over again. Young salmon become adults. Adult salmon produce young salmon. Those young salmon become adults . . . and so on. Our English word *cycle* comes from a Greek word meaning *circle*. A life cycle is a kind of circle of life. Do you see how the travels of the salmon is a life cycle?

It would be fine if you could get a salmon egg or two and watch them. For most of us that is not possible, however. You *can* observe another kind of egg, a snail's egg. One way that salmon eggs are like snails' eggs is that both kinds have a clear jelly around them. This jelly protects the egg. You can observe some things about eggs by doing the investigation on the opposite page. Then we will return to the salmon eggs.

AN INVESTIGATION into the Hatching of an Egg

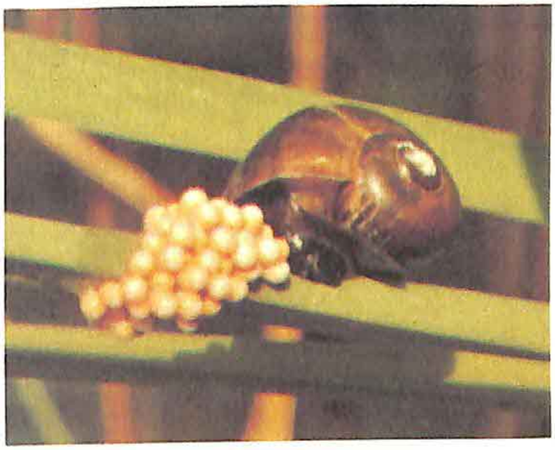
Needed: a planted aquarium with snails in it, a hand lens, a dish, a medicine dropper

The planted aquarium pictured here has snails in it and guppies and other fish. This snail has a coiled shell. ■ It lays eggs on the sides of the aquarium. ● The snail with a spiral, pointed shell lays eggs on the underside of leaves. ▲

The eggs are protected in a kind of jelly. They can be pulled off the surface they are clinging to or scraped off with the medicine dropper. Suck the eggs into the dropper, and place them in some aquarium water in the dish.

Examine the eggs every day with the hand lens. Observe when the snail begins to move in the egg. When does the snail leave the egg? How does it get out? When the tiny snails hatch, feed them bits of lettuce.

Additional Investigation: Frog eggs are laid in the early spring. Their hatching is somewhat like salmon eggs, although frogs and salmon belong to different groups of animals. If you can get frogs eggs, observe how they hatch.



BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Salmon lay their eggs in the
   a. sea
   b. river
2. When salmon spawn, the male salmon produces
   a. eggs
   b. sperm
3. The young salmon just hatched lives on
   a. yolk
   b. food it catches

USING WHAT YOU KNOW

1. What kinds of animals live in the environment of the adult salmon?

2. What is a fish ladder, and what is it for?

3. How does the salmon develop after it hatches?

4. Put these words and phrases in order so that they show the life cycle of the salmon.

smolt
eggs
parr
up the river
down to the sea
spawning
adult salmon

ON YOUR OWN

In the Library

The eel has a life cycle somewhat like the salmon, with one great difference. Look up the life cycle of the eel. Part of the story is on page 205. For further reference the library will help.

3. To the Ocean and Back

A salmon is a beautiful animal. It is built for the work of swimming in the ocean. It is fitted for living in its watery surroundings. Remember that the surroundings of a living thing are called environment. The salmon is fitted for living in its special environment, or **habitat** (HAB·ih-tat). A habitat is the special environment in which an animal lives. For instance, a mole lives underground. Its special environment, or habitat, is underground.

The Fitness of Salmon

A fish is fitted to live in its environment of water in many ways. The fish can move about in order to hunt and to hide. It can breathe. It can get food and eat it.

When a living thing is fitted to an environment, we say it is *adapted* to the environment. An oak tree is adapted to its environment. The goldfish is adapted to its environment. The salmon is adapted to its environment.

There is a difference between the environment of a goldfish and a salmon. The goldfish would die in sea-water. The special environment, the habitat, of a goldfish is a pond, not the sea. A grown salmon would die in a pond. Its special environment, or habitat, is the sea.

Even if the environment of all fish is water, each fish has a special habitat. In that habitat it finds its special food. An eagle cannot live on grass. A cow cannot live on mice. Each kind of living thing has its own habitat, with its own food. Each living thing is adapted to its habitat. ■

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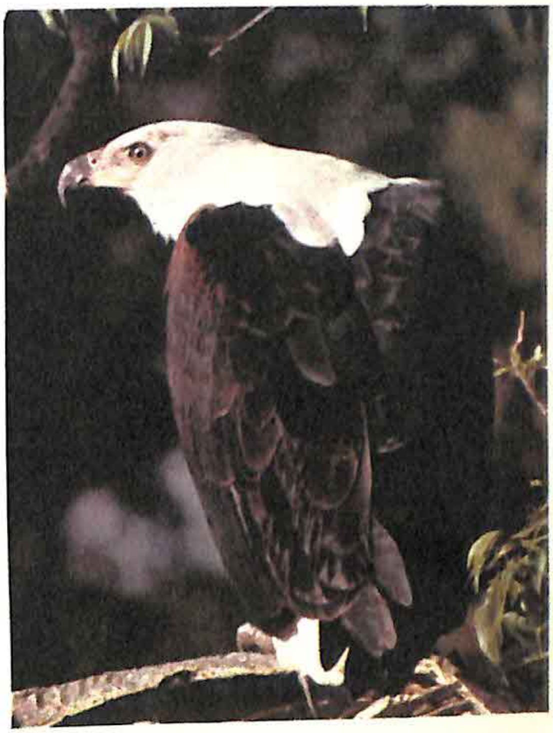


How is a salmon fitted to its habitat? You can investigate this problem with the help of a goldfish, as shown on the next page.

AN INVESTIGATION into the Fitness of a Fish

Needed: a fish (a goldfish will do) in an aquarium

Observe the fish as it swims about. Study it closely, and see how many things you can notice about the fish. Try to answer these questions.

How is the fish fitted for moving about? How does it swim? How does it turn? How does it go up or down?

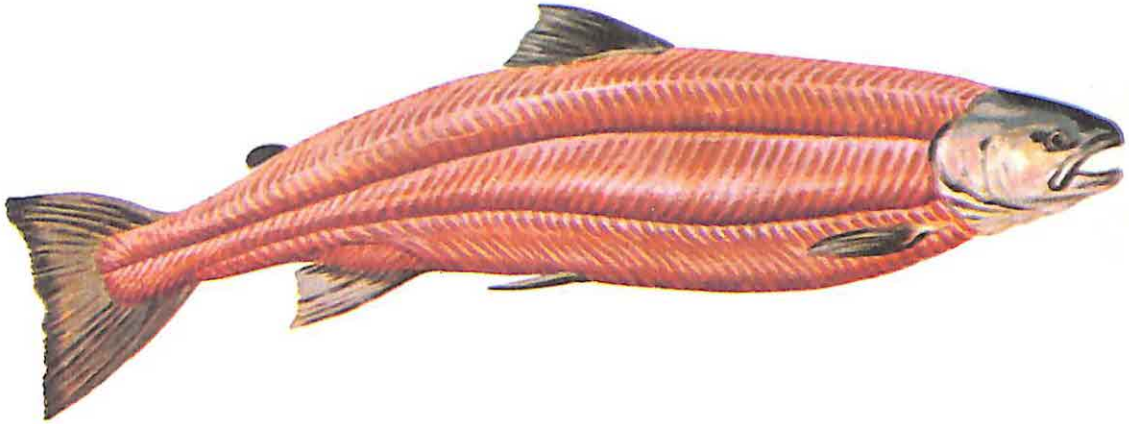
How is the body of the fish fitted for moving through the water?

How is the fish fitted for getting food and oxygen?

The fish's scales are a part of its fitness for living in water. How are the scales placed?

There are openings just in back of the fish's head. How do they move? Do they seem to have anything to do with the fish's mouth? You may be able to see inside these openings as the fish moves them. What can you see?

Does the fish keep its mouth closed or open?



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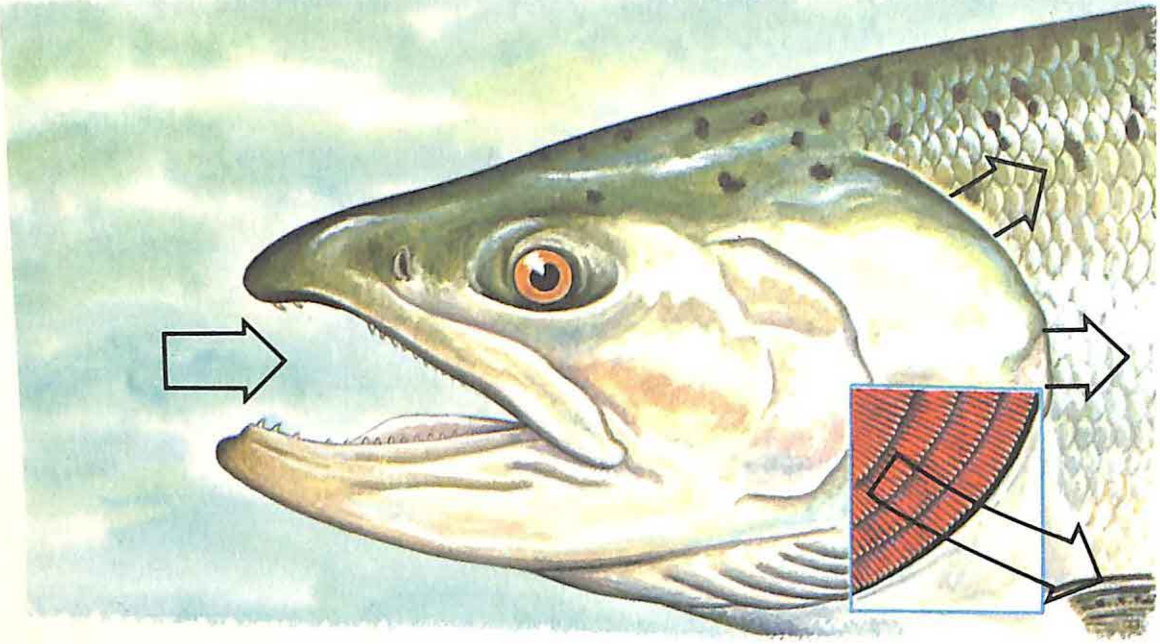
Look at the salmon's adaptations for moving about. Look at the salmon's muscles. ■ Notice how they make a kind of zigzag pattern. Almost the whole body of a salmon is made of muscle. (When you eat salmon, you eat muscle, mainly.) It is these powerful muscles that make the salmon fit for fast swimming, turning quickly, and leaping high out of the water. The powerful tail drives the salmon along. The two chest fins are for steering. See how the body is streamlined, like the shape of a fast airplane. With this shape the body moves more easily through the water.

Notice another part of the salmon's equipment, its shiny scales. They lap over each other like shingles on a roof. Strangely enough, scales have much the same job as shingles. Scales keep water out of a fish's body. If they did not, the fish would take in too much water through its skin. Like a piece of wood that has been soaked in water the fish might become waterlogged.

Let us look at one more part of the salmon's equipment that fits the salmon for living in its environment. The salmon not only gets food from water, it gets oxygen from water. This is something you cannot do, no matter how hard you try. Let us see how a fish does it.

Oxygen from Water

Thoroughly boil a gallon of water. Let it cool, then put a goldfish in



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it. An odd thing happens. A goldfish is fitted to live in water, yet a goldfish in cooled boiled water does not seem at ease. Soon the goldfish comes to the surface. It puts its head out of the water to swallow air. Why?

By boiling the water, most of the dissolved oxygen in the water is driven out. Oxygen, remember, is a gas. It dissolves in water in the same way that sugar dissolves in water. Ordinary water has plenty of dissolved oxygen in it. It is this dissolved oxygen that a fish uses. Boiled water has little oxygen in it, and the fish comes to the surface to get oxygen from the air. It is a good idea to put the goldfish back in its regular water when this happens, for it is not adapted to get enough oxygen from the air to live.

You have probably observed a fish under water opening and closing its mouth, as if it were swallowing something. The fish is taking in water through its mouth. It sends this water through its **gills.** ■ The gills are a fish's equipment for taking oxygen out of water. In the gills dissolved oxygen passes out of the water and into the blood of the fish. The oxygen is carried by the blood to every part of the fish. The gills do for a fish what your lungs do for you: they supply oxygen. Lungs take oxygen from air. Gills take oxygen from water.

There are many other ways in which a salmon is adapted to its environment. After 2 years in the environment of the Pacific Ocean, the salmon that were smolts have become full grown. They are ready for the great journey back to the rivers where they were hatched.

The Return

Now the large, fierce, shining salmon that have roamed the Pacific Ocean for 2 years begin to turn toward the shore, toward the rivers they swam down 2 years before. They are returning to the rivers and streams where they were born. More and more salmon start the return. Soon thousands upon thousands of salmon are swimming through the ocean, headed for the rivers that run to the sea. Their strong, muscular bodies help them to swim fast, without stopping.

They enter the rivers and head upstream. Where rocks and falls break the waters, the salmon leap over them. Sometimes the salmon leap many feet to the next level of the water. They do not stop to feed. They swim and swim. At last they reach the spawning ground in a high, cold mountain stream. All along the Pacific Coast from Oregon to Alaska, salmon return to spawn.● They are thin and ragged. They spawn, the females laying their eggs and the males pouring sperm over them. The eggs settle to the bottom of the river.

The big salmon are finished. After they spawn, still they do not feed. They die. Their bodies are washed downstream. They serve as food for other fish.

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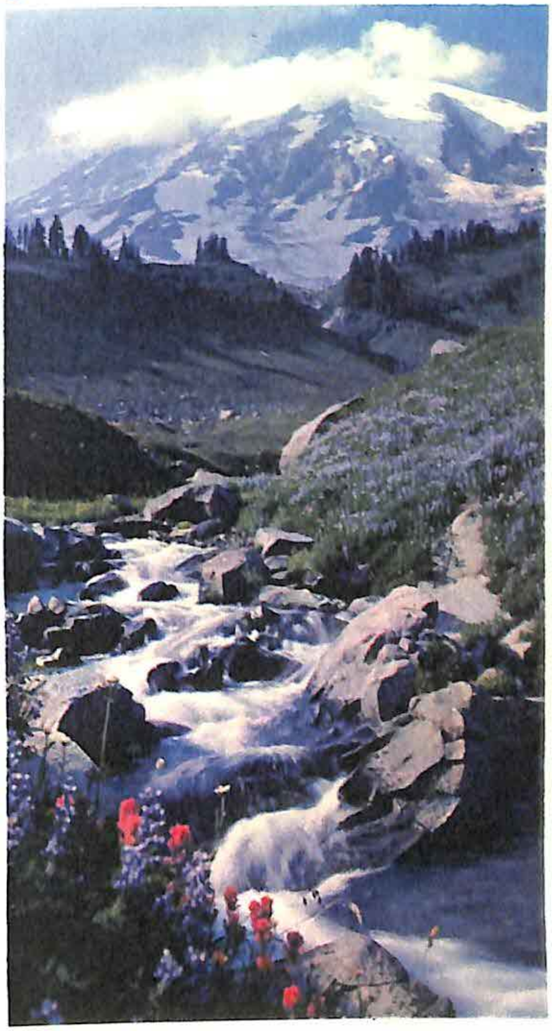
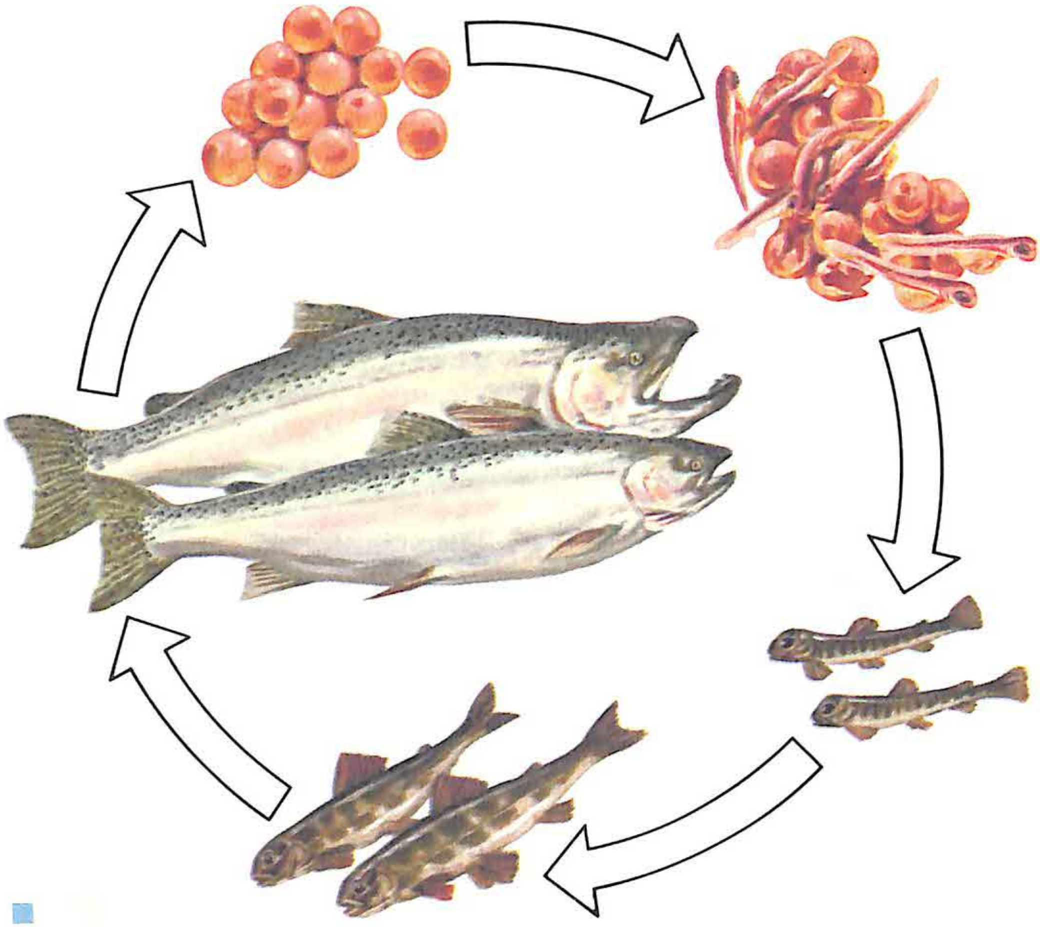




Back upstream, between the rocks, rest the salmon eggs. They will hatch when spring comes. The young salmon with their yolk sacs will burst from the eggs. The spotted parr will flash about in the stream. Then the smolt will head out to sea. The life cycle of the salmon goes on.■

Notice that a life cycle has no ending. It goes on and on. Every living thing has a life cycle. Snakes and frogs and ferns have a life cycle. Oak trees have a life cycle, as you learned in Unit Five. Birds have life cycles, too, as you will soon discover, in studying the next section.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

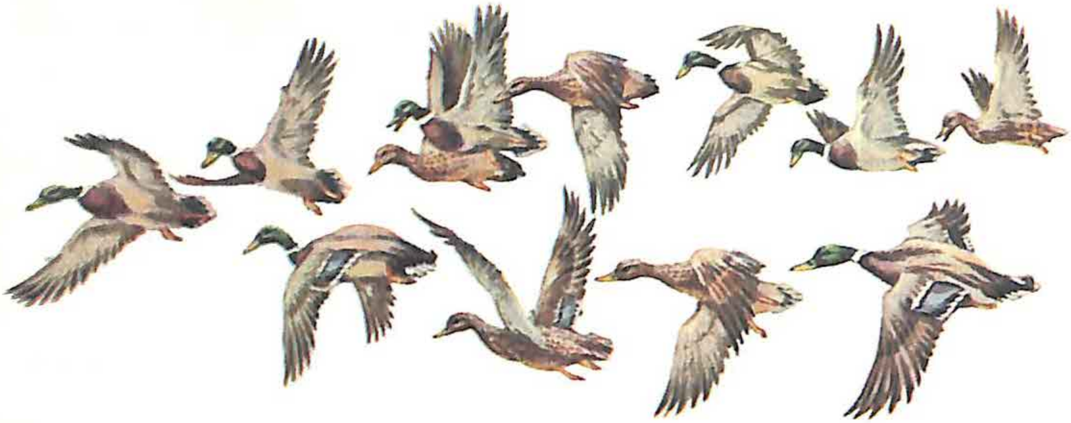
1. A special environment in which living things are found is known as a
   a. habitat
   b. food chain
2. The life cycle of the salmon
   a. ends at death
   b. goes on and on
3. The life cycle of the salmon is adapted to
   a. any environment
   b. a special environment

USING WHAT YOU KNOW

1. A goldfish and a salmon have different habitats. How are they different?
2. A cow and an eagle have different habitats. How are they different?
3. A man and a whale have different habitats. How are they different?
4. In what ways is the salmon not adapted to a land environment?

ON YOUR OWN

How does the habitat of a moss differ from that of a cactus?



4. Salmon and Wild Duck

Salmon fight their way up rivers. In the fall the salmon eggs lie on the river bottoms between the rocks. There they stay during the cold winter.

In the spring the eggs hatch. In 2 years the young salmon head down the rivers toward the sea. For 2 years they live in the sea and become full grown. Then they return to the rivers where they were born. They lay their eggs among the river stones. The cycle goes on. This is the life cycle of the salmon.

The salmon is fitted to this life. It is adapted to its environment. The life cycle of the salmon is really a story of how the salmon is adapted to its environment, isn't it? The story is unusual. Yet the concept of living things being adapted to their environment is not unusual at all. After all, you are adapted to your environment.

Notice that the entire life cycle of the salmon, from eggs to adult to eggs, is adapted for life in the ocean and the river. The whole life cycle of a living thing is adapted to its environment.

There are many, many different life cycles. Let us follow another life cycle. Let us look at the life cycle of a land animal this time—a wild duck.

A Flight of Ducks

Dawn is just starting to shed a pale light over a northern lake, after a cold night. It is early spring. The ice on the lake is beginning to break. It is quiet. A small moving smudge appears in the sky, far off. It gets nearer and bigger. It is a group of wild ducks, flying fast, beating the air with short, strong wings, necks outstretched, feet tucked up, all streamlined. Down they come out of the sky to land on the icy water. This is the end of their journey. ■

Where have they come from? A thousand miles away, in the south.

Wild ducks are real travelers. In the fall, six months ago, they had flown south for the winter months. Year after year wild ducks fly south in the fall and fly north in the spring.

What will they do now that they have come back? Let us look at some of the things they will do.

Near the shores of the lake, among the reeds, the ducks begin to build nests. They are mallard ducks. ●

Like most birds, the male mallard has different coloring from the female. (In the picture, the male mallard is standing by the nest.) The mallards build their nest with leaves and grass and line it with down. Down is the soft, fluffy feathers that grow under the duck's ordinary feathers.

When the nest is built, the female duck lays from six to ten brown eggs in it. Then she sits on the eggs, warming them until they hatch.

You have eaten eggs many times, of course. But have you ever *studied* an egg to see how it fits into the life cycle of the bird? Study a hen's egg. In the investigation on the next page you can do so.

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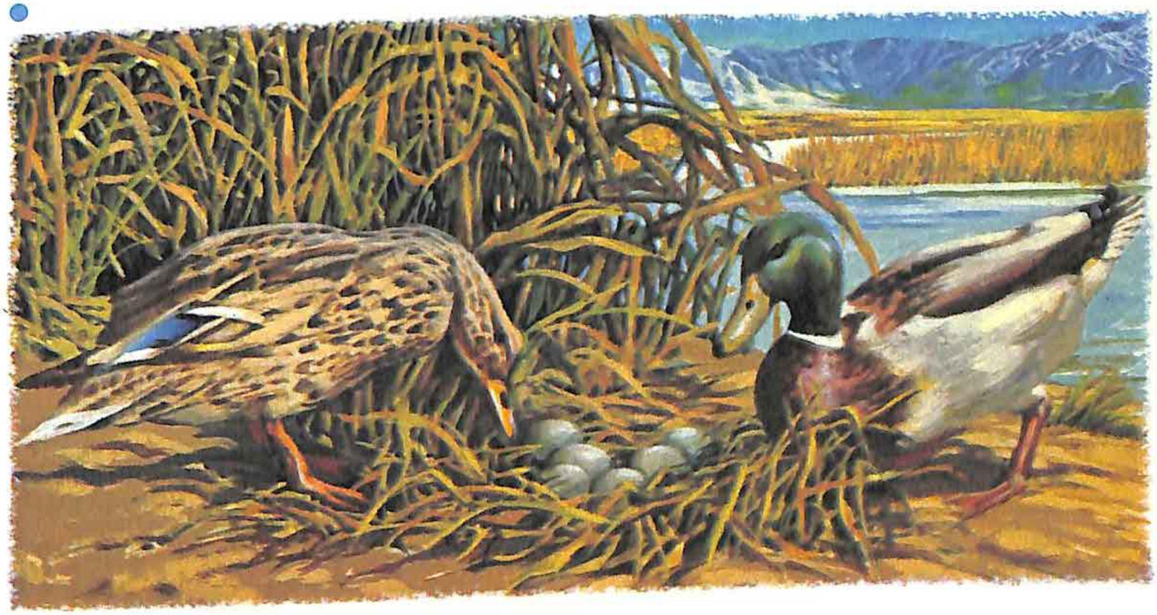


AN INVESTIGATION into a Bird's Egg

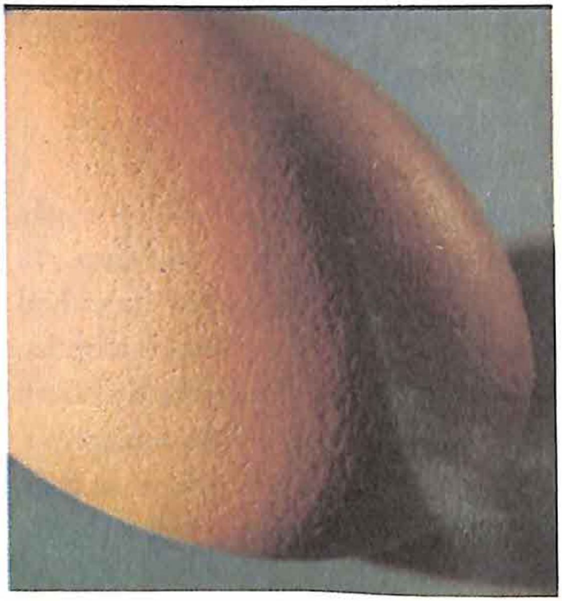
Needed: a hen's egg, a dish, a hand lens

Examine the egg shell with the hand lens. Is it glazed, like a china dish; is it porous? A porous shell has tiny holes in it that let air through. ■

Crack the shell gently. Peel off a chip or two of the shell and notice the skin, or **membrane,** beneath it. ● Air can pass through this membrane.

Open the egg and turn the yolk out into the dish, without breaking it. Look for a white speck on the yolk with the hand lens. This white speck, or **embryo** (EM·bree·oh), is the beginning of the young bird. ▲

The embryo grows while a hen is keeping the egg warm. As it grows, it needs food. The embryo in the egg uses the white and yolk of the egg as food. In about 21 days, the chick hatches from the egg.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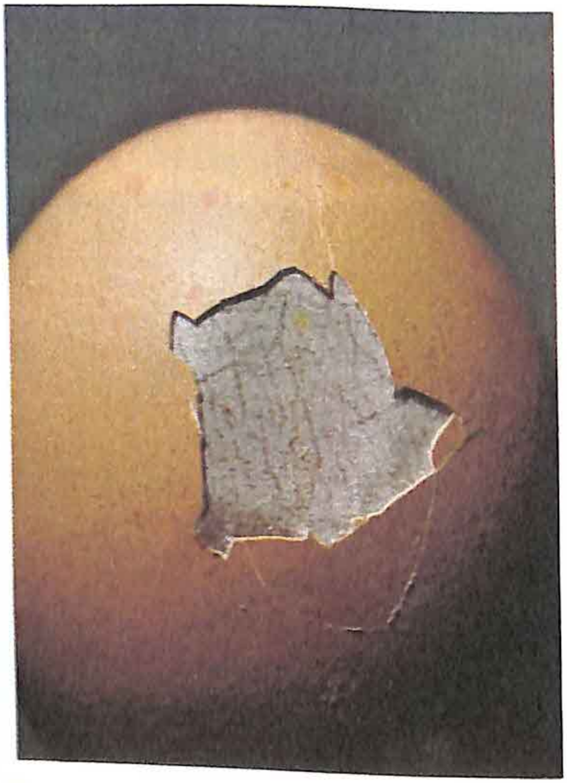
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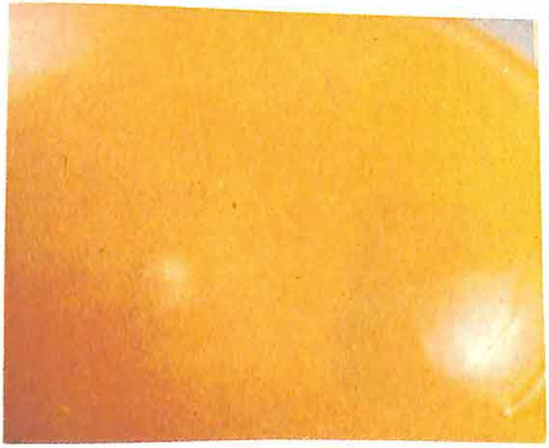
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USING WHAT YOU KNOW

1. Millions of years ago, dinosaurs were found in many places on land. Then the environment changed, but the dinosaurs did not change. They died out.

Can you use the concept of adaptation to explain the dying out of the dinosaurs?

2. How is the duck adapted to flight?

3. How is the duck adapted for hatching its young out of the egg?

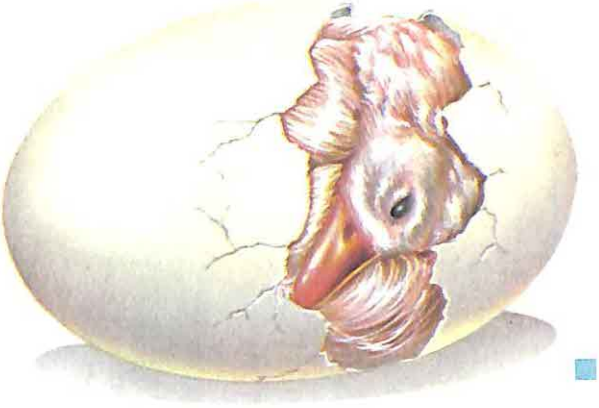
4. How is the egg adapted to the life of the embryo?

5. The Life Cycle of a Duck

The egg of the mallard duck is much like a hen's egg. Its shell is not glazed, but porous. There is a membrane just under the shell, a thin, white skin. There is an egg white, and a yellow yolk inside it. The young duck uses white and yolk for food while it is growing in the shell. And there is a speck on the yolk that is the beginning of the embryo.

Inside the egg the young, growing duck looks like this. ■ Inside the egg it is still an embryo. Notice the beginnings of wings, legs, and eyes.

Just hatched, the duckling can soon walk and feed itself. Is it much different from the adult ducks? In a year it will begin to get the look and the feathers of an adult duck. ●



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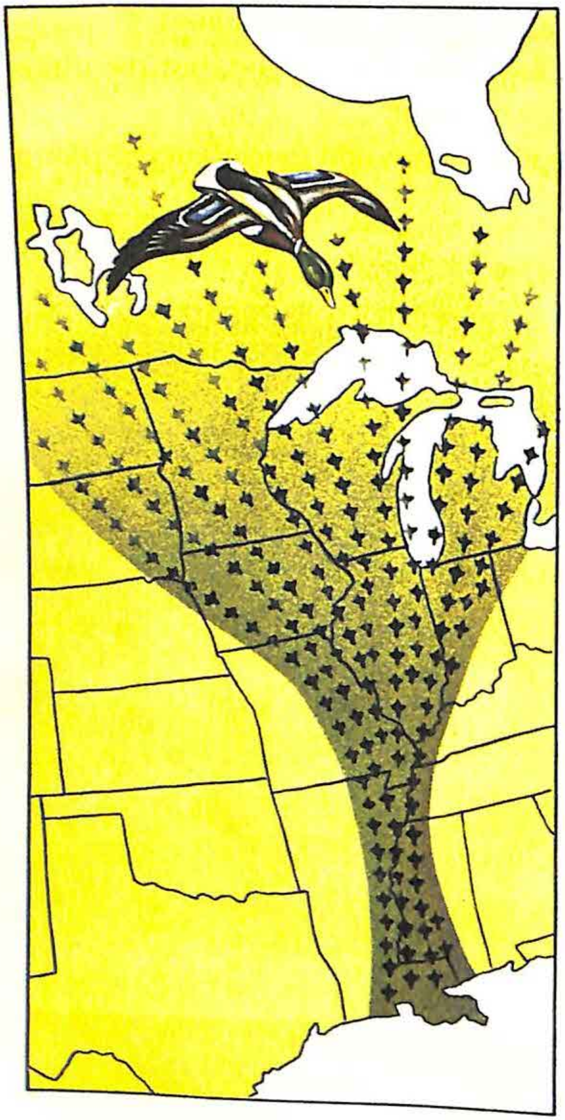


The young of some birds, such as robins and eagles, must be fed by the parents at first. The young of dogs and cats and horses must be fed. So must the young of human beings. But not ducklings! Notice the difference between a salmon and a duck. When a salmon egg hatches, the young salmon carries a yolk sac for almost 6 weeks. Its food is in the sac. But when a young duck hatches, it has used up all the food stored in its egg. The young duck is ready to look for its own food.

To grow from a downy duckling to a handsome duck, the mallard must eat, of course. Like other ducks, mallards like to eat grain, such as wild rice. However, they will eat small frogs, toads, lizards, small fish, snails, earthworms, and even mice. They will eat nuts and acorns, fruits, and many water plants. What a diet! Because ducks can eat so many different things, they can live in many different parts of the country.

Think of this for a moment, too. Whatever a duck eats, it takes from its environment. Whatever a duck eats, the duck's body uses to make itself grow. Everything a duck eats turns into duck.

The Long Journey

Let us look again at those mallard ducks nesting by that northern lake. The mallards are in their breeding grounds, the places where they build their nests and lay eggs. They flew into the breeding grounds in the early spring, you remember. There was still ice on the lake.

As spring turns to summer, the ducklings have been growing. By fall they can fly well. They need to fly, for one day in early winter, when ice is beginning to cover the lake, the whole flock rises into the air and heads south. Flocks of ducks fill the sky, going south and east, where food is plentiful, 2,000 miles away.

One long journey of the ducks is shown on this map. ■ They spend the winter months in the south and east. Then in late winter or early spring they fly back to their breeding grounds in the north and west. This kind of traveling back and forth is called **migration** (my·GRAY-sh'n). Ducks migrate in the fall, and they migrate again in the spring.

This is the life cycle of the duck. ●

How Do They Know?

Ducks fly more than 2,000 miles to their breeding grounds. Then they fly back again. How do ducks know where and when to fly?

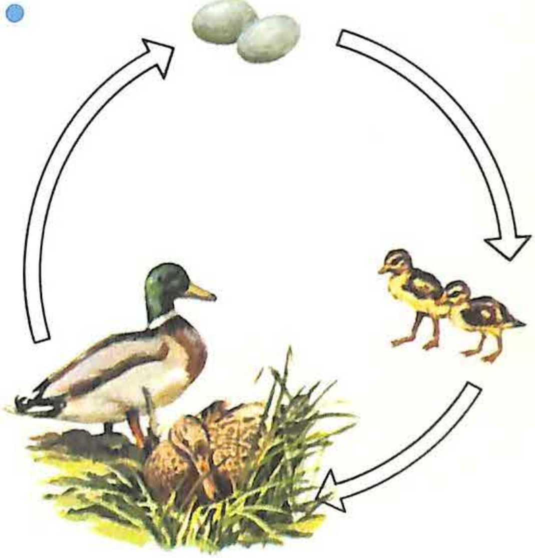
How does a salmon know which river to return to, and when to return?

How do ducks know what kind of nest to build? All mallards build the same kind of nest, even the very first time they build one.

When a duckling sees a hawk for the first time, the duckling does not hesitate. It dives into the water at once and hides among the water weeds. How does a duckling know that a hawk is its enemy?

A female duck will try to lead an enemy away from where its ducklings are hiding. How does the mother know that she should do this, the first time she has young?

How do animals know these things? Do young ducks learn them from their mother? Do young salmon learn from their parents? Or is there some other way by which animals know how to escape an enemy or how to protect their young? Do they have to be taught?



BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Migration of ducks takes place at
   a. any time　　b. a certain time
2. Ducks lay their eggs in the
   a. northern regions　　b. southern regions
3. The life cycle of a duck is fitted to
   a. any environment
   b. a special environment

USING WHAT YOU KNOW

1. A young duck just hatched can begin to feed itself. Can it take care of itself? Is the young duck completely adapted to its environment?

2. What is one important difference between a young salmon (just hatched) and a young duck (just hatched)?

ON YOUR OWN

In the Library

Other birds besides the mallard duck migrate. Select a bird like a swallow, goose, or golden plover. Make a map of its migration. The library will help.

6. Knowing How to Behave

The salmon have their life cycle. The ducks have their life cycle. The young salmon swim out to sea, but return to the rivers to lay their eggs. The young ducks fly south but return, for example, to the northwestern United States to lay their eggs. How do they know how to do these things?

To find an answer to these questions, start with a growing bean. Try the investigation on the opposite page.

AN INVESTIGATION into the Behavior of a Bean

Needed: four jars, four pieces of blue blotting paper, twelve dried bean seeds

Soak the dried beans overnight in water, to make them ready to grow. The water should just cover the beans.

Place three of the soaked beans in each jar, between a piece of blotting paper and the glass. ■ Soak the blotter with water. Examine the blotter every day to be sure that it is moist. Soak it again if needed.

Now place the jars in four different positions. Stand one right side up. Stand another upside down. Lay another on its side. Place the last jar so that it is tilted.

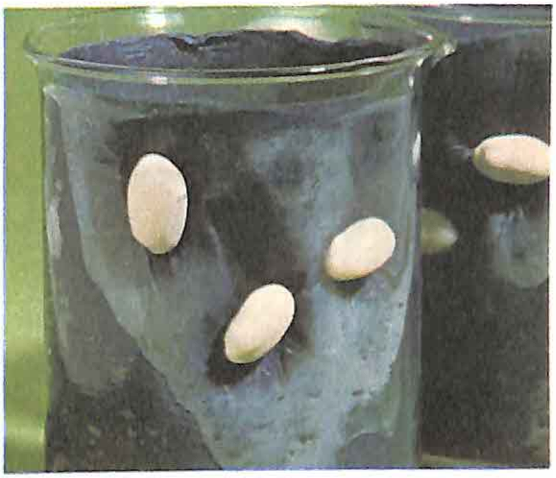
Observe the beans every day.

In which direction do the roots grow? In which direction do the stems grow? Does the position of the bean make a difference?

Here is what happened in one trial. ●

How do you think the beans know how to behave this way?

Additional Investigation: Try this same investigation with corn. Does corn behave the same way?



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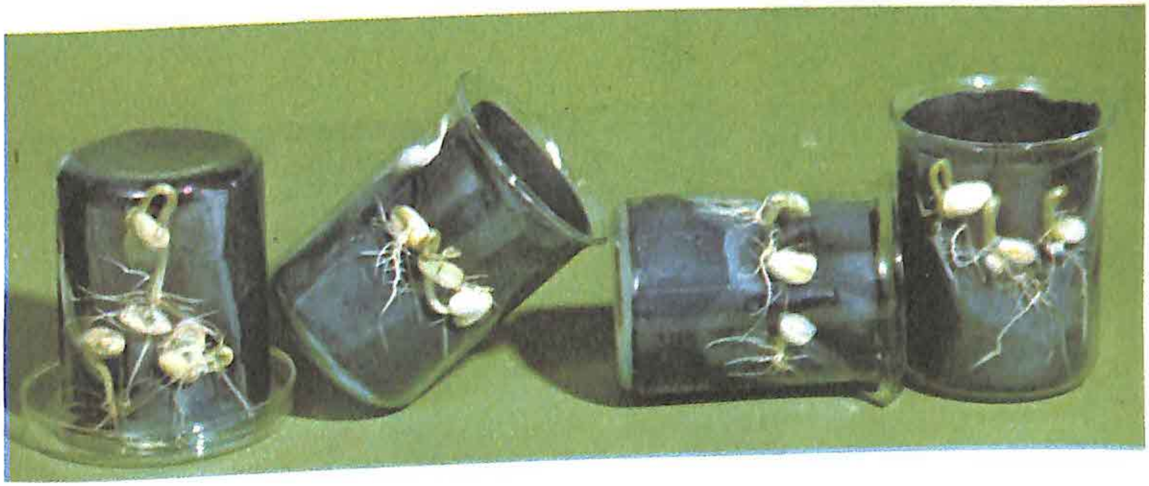

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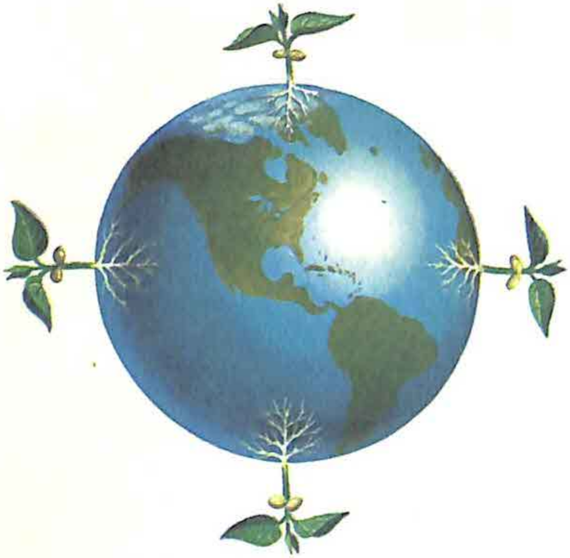


How?

The roots of a bean plant grow toward the Earth. The stem of the bean plant grows away from the Earth. This is the way bean plants behave, isn't it? In fact, the roots of most green plants grow down, and the stems grow up. This is the **behavior** of most green plants. This is the behavior of a bean plant.

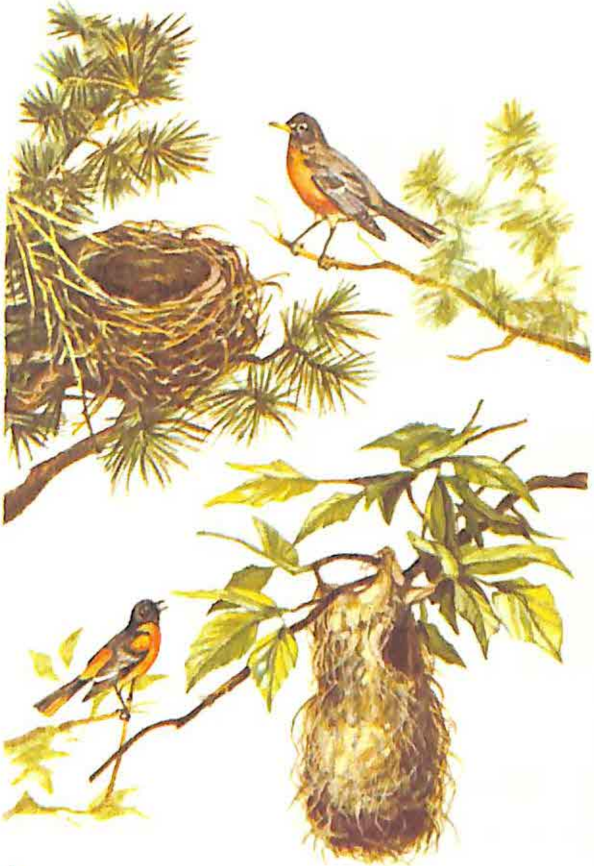
How does a bean plant know this behavior? We are sure that a bean does not learn to behave this way. Beans cannot learn. Learning is not the answer. The answer is that the bean's behavior is built into the bean. The behavior is born in the bean, or in other words, the behavior is **inborn.** This behavior is part of a bean from the moment it becomes a bean. Like its color, its shape, and its size, the behavior of the bean is inborn.

Let us look at another kind of behavior. Perhaps you have seen moths flying around a light. Again and again they bounce against the glass. They cannot seem to get away. Most moths that fly at night are attracted by light and fly toward it. They behave this way from the time they are hatched. This behavior is part of the moth from its birth. It is inborn. It is not learned.

The spider making this web has not learned how to do this. ● The behavior of making a web is a part of the spider from birth. All the spiders of this kind make this kind of web. This behavior is also inborn. It is not learned.

It is the same with nest-building in birds. Birds separated from their parents from birth make the same kinds of nests as the parent birds. All eastern robins make the same kind of nest. All Baltimore orioles make the same kind of nest. ▲ All mallards make the same kind of nest. Nest-building is inborn behavior.

Mallards migrate. So do other kinds of birds: robins, wild geese, and many song birds. Salmon migrate. So do other kinds of fish. Along the Atlantic Coast the shad, a salt-water fish, migrates into fresh-water rivers to spawn.



▲

Eels in rivers along the East Coast have an interesting life cycle. Eels are hatched in warm waters in the Atlantic Ocean. The young migrate when they are about one-year old. They enter fresh-water rivers where they live for six or seven years. Then they migrate to the warm Atlantic to spawn. Salmon, too, migrate, as you have learned.

Birds and fishes do not learn to migrate. Migration is a kind of behavior that is inborn.

■

When?

In the spring, salmon start swimming to the sea. In early spring, mallards start flying to the northwest. How does a fish or a bird know *when* to migrate?

Scientists have investigated this question. For example, scientists did some investigations with the birds pictured here, called juncos (JUNG-kohz). ■ Juncos migrate. They begin to fly north in the spring. Scientists wondered if they could make some juncos migrate earlier than usual. If they could, they might have a clue to what made juncos migrate at a certain time.

You know that the days get longer as we go from winter to spring. Some scientists suspected that the length of the days might have something to do with when juncos migrated. So some juncos were kept in barns. Lights in the barns were turned on and off to control the length of "day" in the barns. When the days became about 8 hours long, the juncos began to get ready to migrate. When the days became about 10 hours long, the juncos began to migrate.

It was the number of hours of daylight that set off the juncos' migration. The amount of daylight seemed to be the **stimulus** (STIM-yoo·lus) for migration. A stimulus is anything that produces a **response,** or answer. A bright light is a stimulus which attracts moths. The flight of the moths toward the light is their response. When you respond to hearing your name called, you are responding to a stimulus. You may respond by doing something when your name is called.

When the length of the day reaches a certain number of hours, it is a stimulus for juncos. The juncos respond to this stimulus by migrating. Mallards begin to migrate when the days are about 8 hours long. Other kinds of birds may migrate at other times. Different birds are adapted to migrate at different times. Each kind of bird is adapted to its environment.

Each kind of fish is adapted to its environment, too. When the ocean water in which the salmon swims reaches a certain temperature, the salmon begins to migrate. The salmon is adapted to its environment.

All living things are adapted to their environment.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A moth flies toward a light. We expect that this behavior is
   a. learned
   b. inborn
2. The migration of a duck is
   a. learned
   b. inborn
3. A stimulus leads to
   a. a response
   b. another stimulus

USING WHAT YOU KNOW

1. What kind of inborn behavior do you expect from the stems of plants? How is this different from the inborn behavior of the roots?

2. What evidence is there that nest-building in birds is not learned?

3. Do *you* have any inborn acts? What is the evidence that they are inborn?

ON YOUR OWN Do you know of any animal or plant that is adapted to *all* environments?

7. The Main Concept: Adaptation to Environment

You have studied the strange behavior of salmon and ducks, the strange behavior called migration.

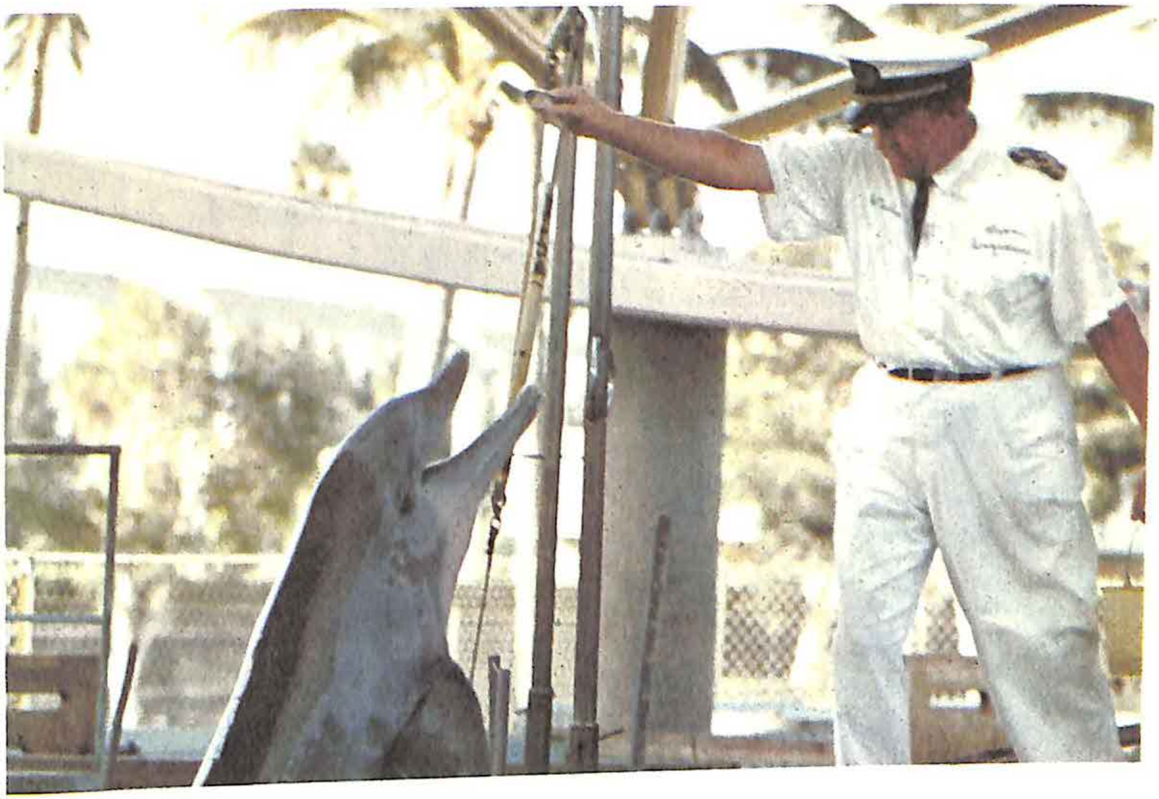
Is it right to call this behavior "strange" now? This behavior is the way of life for the Pacific salmon and for the mallard duck. Their migration behavior is inborn. Salmon and duck are adapted in this way to their environment from the moment that they hatch.

Notice that adaptation has two sides to it. One side is adaptation by structure. The salmon is adapted by the structure of its body to live in water. Its gills enable it to get the oxygen dissolved in water. Its fins enable it to swim in water. Its body cuts a path through the water easily. The salmon is not adapted to flight in air; the duck is. Structure helps adapt a living thing to its environment.

But structure is not the only thing that helps adapt a living thing to its environment. A living thing is also adapted to its environment by its behavior. For instance, migration is one kind of behavior. Adaptation is helped by the behavior of a living thing, as well as by its structure.

Do not think that all behavior of a fish or a bird is inborn. A bird or a fish can learn some things. A fish, for instance, can learn to come to one corner of its tank for food. It may learn *when* to come, too. This keeper is feeding a dolphin in an aquarium in Florida. ■ Even before the keeper comes to feed it, the dolphin is waiting at the place where it is fed. This behavior is not inborn, it is learned.

From what scientists know now, the behavior of migration is inborn.



However, scientists are still studying migration. It is possible that they may discover that some part of the behavior of migration is learned. Just the same, this behavior is part of the life cycle of these living things. Migration is an example of how salmon and ducks are adapted by their behavior to the environment in which they live.

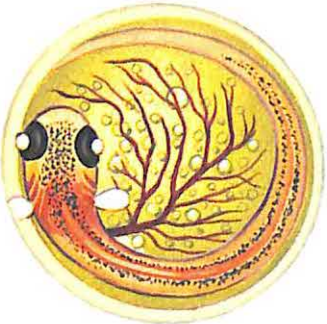
A Pacific salmon is hatched in a river, grows, and goes out to sea. A few years later it returns to the same river and lays its eggs. The salmon has completed its life cycle. This life cycle adapts the salmon to its environment. A mallard flies northward, more than 3,000 miles, to lay its eggs. Each year the duck makes this flight to continue its life cycle. This life cycle adapts the duck to its environment.

Salmon and ducks are living things. Like all living things, they are adapted to their environments. What is more, they are adapted to special habitats within their environment. Adaptation to their environment makes living things part of the life and land and water around them.

Fixing the Main Concepts

TESTING YOURSELF Study the statements below and choose the correct responses. Your study will help fix in your mind the main concepts of this unit.

1. A salmon hatches from an egg in
   a. a stream b. the ocean
2. A smolt makes a journey toward
   a. a stream b. the ocean
3. Male and female salmon become adults in
   a. a stream b. the ocean
4. Male and female salmon journey back to
   a. a stream b. the ocean
5. A duck begins its life, hatching from the egg, in
   a. northern lands b. southern lands
6. The embryo shown in the picture below is a young
   a. fish b. bird



7. The fitness of a duck for flight is known as
   a. migration b. adaptation

8. The structure of a fish adapts it to take dissolved oxygen from

a. water b. air

9. The structure of living things adapts them to their habitats. This is true of

a. all living things b. animals only

FOR YOUR READING

1. *Winter-Sleeping Wildlife,* by Will Barker, published by Harper & Row, New York, 1958. This is an interesting account of the many ways of adaptation of wildlife to environment. You may particularly want to study hibernation, the winter-sleeping adaptation of bears and other animals.

2. *Insects and the Homes They Build,* by Dorothy Sterling, published by Doubleday and Company, Garden City, N. Y., 1954. Insects sometimes adapt to the environment by building shelters or traps, such as cocoons, honeycombs, and webs. This book is a good account of adaptations of living things.

3. *The First Book of Birds, The First Book of Mammals,* both by Margaret Williamson, published by Franklin Watts, New York, 1951 and 1957. These are simple accounts of what makes a mammal a mammal, and a bird a bird. Each is a beginning book of the adaptations of mammals and birds.

4. *Animal Life and Lore,* by Osmond P. Breland, published by Harper & Row, New York, 1964. Here are answers to many questions about animals and their ways, from "How does a cat purr?" to "What is the most dangerous animal in the world?" There are lively and informative essays on many different creatures, as well.

5. *The Pond,* by Robert Murphy, published by E. P. Dutton and Company, 1964. A story about Joey, the young hunter and fisherman, and his adventures and discoveries in the world of nature around and in a pond.

GOING FURTHER

1. Living things are adapted to their environment by means of their *structure* and their *behavior*. The gills and fins of the salmon adapt it to live in water. The wings of the duck adapt it to flight in air. The behavior of both salmon and duck adapt them to a change in habitat.

Can fish adapt to a *sudden* change in the environment? Perhaps you have an aquarium in your classroom. For this investigation it must contain at least two fish – or better yet, two kinds of fish. If you have tropical fish, you might use guppies and zebras, or two other types. The fish should have been in the aquarium for some time.

Separate the two types of fish in the aquarium with a glass plate. Your teacher will help get a piece of glass cut so that it will fit. Devise a way to support the glass plate so you have two separate compartments.

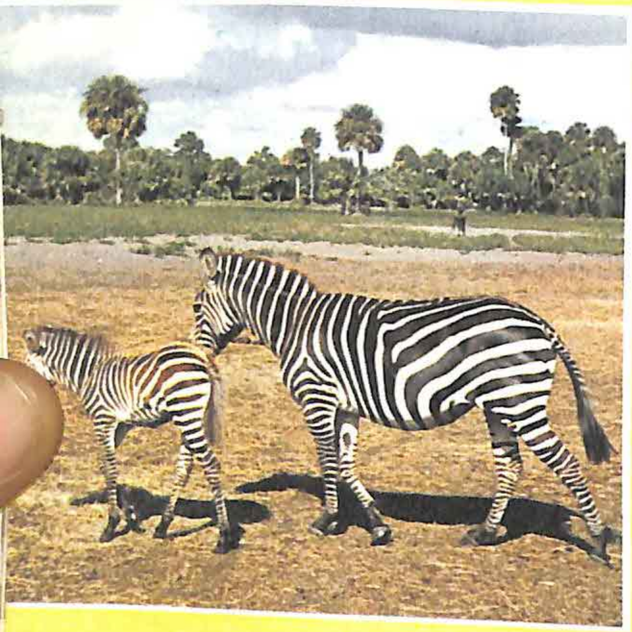
What happens? How do you explain the fishes' behavior?

2. Do you know that moths have an interesting life cycle with a strange adaptation? At a certain time in their life cycle, moths change form and go into a type of hibernation called a *diapause* (DY·uh·pawse). During this period they form cocoons, such as these. ■

Many boys and girls have taken up the hobby of collecting cocoons. They care for the moths which come from the cocoons and mate the moths to get eggs. A good way to begin is to read *Collecting Cocoons,* by Lois J. Hussey and Catherine Pessino, published by Thomas Y. Crowell, New York, 1953.

This book describes the life cycle of moths, and how to collect cocoons. There are instructions on how to care for moths as well.

In the study of cocoons, you will study the life cycles of some very interesting organisms.



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A New View of Living Things

We expect a bean seed to produce a bean plant, not a corn plant. We expect elephants to reproduce elephants, not horses. A duck's egg is expected to produce a duckling, not a chick.

Why do we expect each living thing to reproduce its own kind? Because we know that parents pass on their own characteristics to their young. The acorn of a white oak produces a white oak tree, not a red oak tree, because the parent tree passed on to that acorn the characteristics of a white oak. It is a duckling that pecks its way out of a duck egg because the parents pass on those characteristics. Living things reproduce their own kind. ■

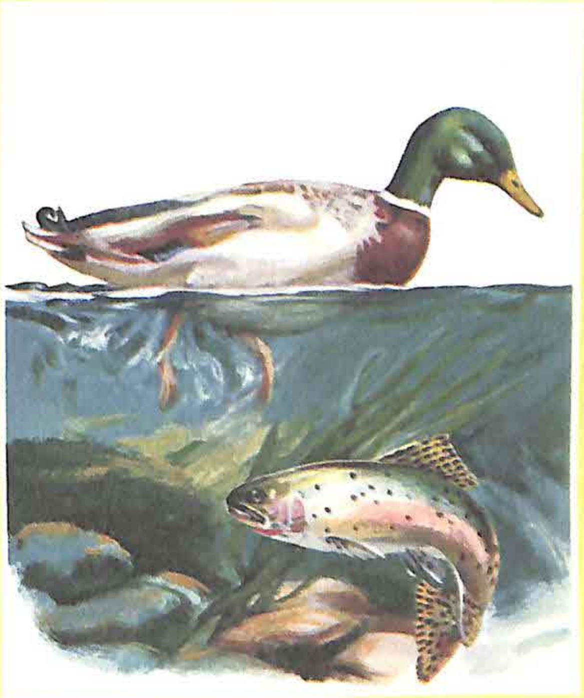
If . . .

Living things reproduce their own kind. There is an "if," however.

Suppose that a mallard duck laid its eggs in a cold stream where salmon lay their eggs. You can guess what would happen to the duck eggs. They would not develop. Nor would the salmon eggs develop if they were laid in a place that became dry. A living thing cannot reproduce anywhere. It must have a special environment for its young to develop. In fact, a living thing is adapted to a special environment.

Think of a fish and a duck.● Each is adapted to a special environment. The fish gets its oxygen from water. The fish is adapted to get oxygen in this way by means of its gills. The duck gets its oxygen from the air. The duck is adapted for this by means of its lungs. Fish or duck, each is adapted to a special environment.

It is no different with plants. Why shouldn't a white oak seedling and a staghorn sumach seedling grow in the same place? After all, both have stems and leaves and roots. Yet the white oak grows best where soil is moist. The staghorn sumach grows best where soil is dry. Each has its own best environment. A small difference in that environment, as it seems to us, may mean the difference between good growth and poor growth—or none at all. (This is just as true for you as for white oaks and sumachs.)



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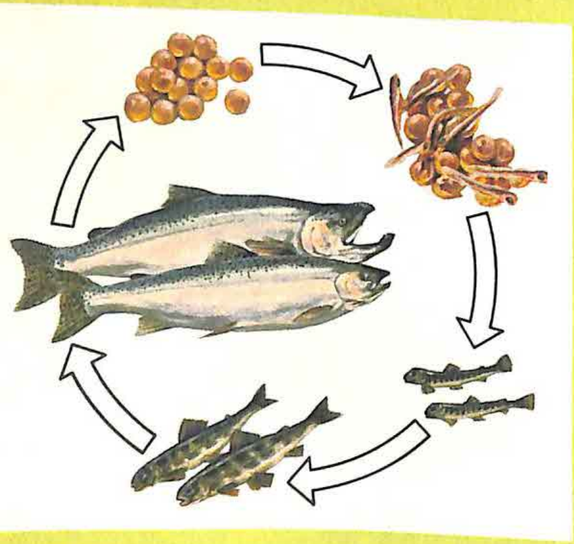
Changing Environment

A living thing is adapted to a special environment, but this doesn't mean that the environment is always the same. Some living things adapt themselves to a different environment at certain times. Think of the life cycle of the salmon, for example. ■

At a certain time in its life, an adult salmon is adapted to living in the fresh water of a stream. It does not lay its eggs in the sea. The eggs develop only in the environment of the stream. So do the young salmon. Then, at a certain time, the young salmon changes its environment. It goes to the sea. There it grows to be an adult. But to complete its life cycle, it migrates again in a long and difficult journey back to the stream where it was born. It cannot complete its life cycle unless it does this. It is completely adapted to two different environments.



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A Part of the Environment

Living things reproduce their own kind.

Living things are adapted to their environment.

These are two important and broad concepts, certainly, for they apply to every living thing. With these concepts in mind, you can look at *any* living thing and understand that living thing better.

There is one more concept.

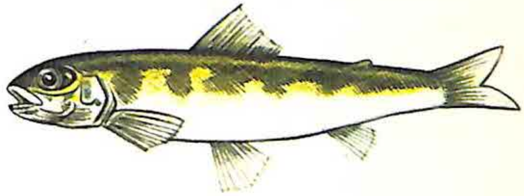
Do you recall what the young salmon ate as food? ● The young salmon fed on other, smaller living things —simple single-celled animals and plants (called protozoans and algae). These smaller living things, then, were a necessary part of the young salmon's environment.

You may remember, however, that the young salmon's life was a risky one. For other living things, larger than the young salmon, fed upon the young salmon. For these larger fish, the young salmon was a part of *their* environment. (We feed on salmon, too.)

So the young salmon was not only adapted to a certain special environment, but it was a part of the environment itself. This is true of all living things. Living things are not just adapted to life in a special environment. Living things are part of the environment.

The white oak growing in the woods is adapted to that special environment. But it is also a part of that environment itself. When it falls and dies, fungi and bacteria feed upon it; it decays and becomes part of the soil. Other seeds grow in what was once a tree.

Living things not only depend on their environment. Living things are part of it.



●

CONCEPTUAL SCHEME

Living things are in constant change.

(*Text pages 218–53*)

Unit Seven

THE TRAVELS OF A HANDFUL OF SOIL

UNIT CONCEPT
The environment is in constant change.

Children investigate the forces which are constantly changing in the Earth's surface. They discover that as land is broken down in one place, it is built up in another.

A Preview of the Concepts

A VIEW OF THE UNIT

Understanding orderly and predictable change is an important objective of any science unit and in particular of this one. Children become aware that there are twin forces at work which are constantly changing the Earth. These changes, as children know, change the environment of living things. The breaking up of rocks into soil gives a foothold for plants such as lichens; the flooding of valleys enriches the soil and larger plants and trees can grow, providing food for the great variety of Earth's animal life.

The fundamental concept of constant change in the Earth's crust is based on actual observations. Although these changes may be slow and slight, their cumulative effect produces the major physiographic forms of the Earth's surface. Land forms may be changed quickly by earthquakes, landslides, floods, and the like, but most changes are so gradual as to be almost unnoticeable within the span of a human life.

Conditions or factors which affect land formation in a given area are the kind of rock, the rock structure, the agents or processes at work, and the relative geological age or stage of the region.

Most agents or processes of geological change can both build up and tear down. Streams cut in one place, only to build in another; so do wind, waves, glaciers, and gravitation. Volcanoes, earthquakes, pressure of sedimentation, and rock faulting, in general, elevate land; wind, rain, streams, and glaciers wear down the surface.

The wearing away of mountains and the formation of new land at the edge of the sea goes on all the time. As a result, the Earth's crust wrinkles. Earth wrinkles occur at the weakest places, where the bending of the crust is the easiest. Since inland seas and coastlines are wear places, Earth's crust began to fold here into what we know as mountains. Over millions of years huge mountains rose where once had been only water. Gradually over more millions of years, these mountains have worn lower and lower, as rock and soil are carried into the sea.

SUPPLEMENTARY AIDS

All films and filmstrips are in color, and all are rated as suitable to the level of reading and comprehension of concepts for this textbook. Names and addresses of distributors and suppliers are on page F-25.

Films

Face of the Earth (12 min.), E.B.F. Reveals the forces that wear down the Earth: the action of running water, glaciers, and landslides; also the forces that build up the Earth, which result from internal pressures of volcanic action; demonstrates that the Earth's surface is constantly changing.

Our Earth (12 min., sound), Cenco, 1963. Explains that the Earth is made up of masses of land, water, and air; how the changes of the surface, or crust, have been caused by sedimentary deposits or by intense heat and pressure.

Birth and Death of Mountains (12½ min.), F.A. Shows that although mountains appear permanent, they are ever-changing; how water, ice, and wind break them down and how underground forces are constantly at work building them up.

Earth's Changing Surface (12 min.), McGraw-Hill. Discusses the effects of water, wind, and temperature in wearing away the land; and how the forces of volcanoes and earthquakes help in building up the Earth's surface.

Filmstrips

Story of Mountains (50 frames), E.B.F., 1953. Explains how the surface of the Earth is constantly changing as a result of erosion, land-sinking and upthrusting; how shifting sands and the freezing and thawing of water cause changes.

Building the Soil (52 frames), McGraw-Hill, 1962. Shows how soil is made from rock particles, lichens, and from decayed plant and animal life; how plant roots help hold soil; how dead trees provide food for fungi, plants without chlorophyll.

Changing Surface of Our Earth (46 frames), McGraw-Hill, 1953. Shows that the Earth's surface is constantly changing; erosion or wearing away is caused by running surface water, underground water, wind, and sand; building up is caused by sedimentary deposit, surface folding, and volcanic pressures within the Earth.

How Soil Is Formed (36 frames), McGraw-Hill, 1960. Shows how rock is broken down by water, ice, wind, and temperature changes; how humus is added to rock particles; the importance of this topsoil to man.

Science Reading Table

Starred (*) titles are considered especially suitable for conceptual development or the reading level indicated. Other titles have excellent sections for certain concepts developed in the textbook. Names and addresses of the publishers are on page F-24.

**All About Mountains and Mountaineering*, by Anne Terry White, Random House, 1962. Description of how mountains are formed and their most spectacular features introduces the reader to the mountain ranges of the world. Famous mountaineers' accounts of exploration of the Alps, the Rockies, the Andes, and the Himalayas bring the reader close to the magnificence of the structure and characteristics of mountains. The several photographs are excellent. (Advanced)

All About Our Changing Rocks, by Anne Terry White, Random House, 1955. Contrasts the wearing down of the Earth with its building up. Includes information on fossils, minerals, and the science of geology. (Average)

°*The Desert,* by A. Starker Leopold and the editors of *Life*, Time, Inc. From the *Life* Nature Library; Silver Burdett, 1964. Many Earth movements and soil changes are described in this comprehensive book. Stories of the plants and animals which inhabit the desert, as well as the structure of the desert itself, are narrated interestingly and pictured in many full-page color photographs. Teachers and pupils will enjoy using this book for extended reading and reference. (Advanced)

How to Grow House Plants, by Millicent E. Selsam, Morrow, 1960. Complete directions for care of plants indoors. The factors of water, temperature control, soil selection, fertilizers, and insecticides are described. Investigations that vary the factors are suggested. (Advanced)

The Soil Story, by George Shaftel and Helen Heffernan, from the *Man Improves His World* series, L. W. Singer, 1963. The introductory fictional story "Black Blizzard" describes a desperate soil problem and what one family did about it. The major portion of the book narrates comprehensively and in detail the properties of soil, soil use and misuse around the world, the problems of erosion and soil management. A concluding section, "The Mediterranean Development Project," discusses many causes of soil depletion and what can be done about them. (Advanced)

°*What Is a Rock,* by B. John Syrocki, Benefic Press, 1959. An introductory study of the general appearance and characteristics of rocks. Describes how rocks are formed, how they wear away, the evidences of life found in rocks and, briefly, the uses man makes of rocks. (Average)

What Is Soil, by B. John Syrocki, Benefic Press, 1961. The many ways in which soil is formed and the forces that contribute to soil formation are described. The importance of soil to living things and the role of plants in soil retention and use are stressed. (Average)

°*Your Changing Earth,* by Hy Ruchlis, Harvey House, 1963. Emphasis is on the changes the Earth has undergone from its probable gaseous beginning to the present time. The description of how the Earth is changed by wind, water, and living things helps to develop the concept of the magnitude and continuity of change. (Advanced)

▶ INTRODUCING THE UNIT

What have rapidly moving water, freezing ice and snow, sunlight, and growing plants to do with constant changes in the Earth's surface? In this unit you will find out about the forces that wear down and build up the Earth.

As a prelude you may wish to read or place these lines by Tennyson on the chalkboard:

> The hills are shadows, and they flow
> From form to form, and nothing stands;
> They melt like mists, the solid lands,
> Like clouds they shape themselves and go.

Ask children what they think the lines mean. Accept all suggestions. Then, when this unit has been completed, you may wish to return to see how a study of the Earth's constant changes enables children better to interpret these lines of poetry.

Section 1: THE MOVING LAND

(Text pages 220–24)

SUBCONCEPT
The energy of moving water changes the Earth's surface.

Children gain understanding of how running water moves soil, rock, and other bits of matter from one place to another.

Introducing the Concept

Processes emphasized

- Development of geological models
- Observation (field trip)
- Analysis of observations
- Categorizing
- Mapping
- Hypothesizing
- Theorizing
- Prediction

Do the children in your class live near an ocean, river, or lake, in the mountains, or on the plains? A discussion of familiar terrain makes a helpful beginning. Pictures of mountains, rivers, waterfalls, forests, prairies, or deserts might be displayed about the classroom. From the familiar, children may then study the unfamiliar and form hypotheses for later investigation. A trip outdoors, even around the school grounds, will enable children to see landscape features in miniature. Some questions to guide observations might be: Has the soil always been where you see it now? Where did the soil come from? How did it get there?

Before the children begin the investigation on text page 221, let them consider this key question:

What is the action of rivers?

Developing the Concept

Children infer that water carries soil from place to place.

Equipment and Materials

See text page 221; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. Start immediately with the investigation. If an aquarium is not readily available, a cardboard carton can be used. Place the carton outdoors. Pile sand in one corner of the box. Proceed as described in the text. You may wish to add some colored sand to the pile in order to see more clearly how these particles are carried downhill by the water. The additional investigation asks a question that will be investigated in Section 5: How does cover (grass or leaves) slow down the washing away of soil in heavy rains?

After a rain, a walk around the school grounds to observe how miniature rivers develop in open soil and how soil is washed from yards onto streets and roads will add meaning to the investigation.

Water can carry soil over long distances.

Where does soil travel? Encourage children to observe closely the picture on text page 222. What do they think happens to the soil along the river banks when it rains? (Rain washes some of the soil into the river.) Where does the soil go once it is washed into the river?

Where does the nearest river in your community run? How far would a grain of soil travel from where you are until it reaches the sea? How far might a grain have traveled before it reaches your point on the stream? Children may estimate distances on a topographical map of the United States. Decide what big rivers might carry soil on long journeys. (The Mississippi, the Colorado, the Columbia, the St. Lawrence.) Through how many states might a grain of soil pass from the headwaters of the Mississippi to its delta?

Moving water contains many particles of soil.

Equipment and Materials

. . . glass or jar
. . . soil

Muddy water. Why do you think the water in the picture on page 223 looks brown? (It is muddy.) What happens to the mud when water stops moving? How can we find out? A child will likely suggest making a sample of muddy water in a glass or jar and allowing the particles to settle. This condition may be simulated by stirring a few spoonfuls of soil into a jar of water and watching what happens to the soil particles as the jar is allowed to stand. How does the water look then? Now shake the jar of soil and water. Why does the water again appear muddy? (Movement mixes soil with water.)

Extending the Concept

A river trip. Following a river is fun. If a river or creek runs near your school, plan a field trip. (It should be under adult supervision.) Walk along the river's edges to explore its banks and see the riverbed, if you can. Does the river move fast or slowly and why? What is the bed like? What kind of course does the stream take? Is there much loose material which is washed downstream? Does the water appear clear or muddy?

When children return to the classroom, they may wish to write accounts of their river trip.

Equipment and Materials

. . . outline or topographic map
. . . colored yarn
. . . pins
. . . cardboard

Where does a river run? Study a map of the United States. Five oceans cover about three quarters of the Earth's surface. Do these oceans join together? What do you notice about the pattern of rivers? Suggest that children take turns tracing the flow of water from small streams to rivers and lakes and eventually into the ocean. Devise a way to "animate" the pattern of a river, using maps, yarn, and pins on cardboard. Show the courses of the large rivers of the United States. Or make charts, tracing the flow of rivers near or through your community. Children will be eager to display their work.

A model of a river and its tributaries might be shown by holding up a bare tree branch in front of the class. Most children know that food made in the leaves travels all the way to the roots. Ask them if they see how the twigs are like very small rivers, the branches like large streams, and the main trunk like a huge river. (The river carries materials from the smallest rill down to the end of the largest river where the materials are then deposited in the ocean.)

A changing river bank. A model river can give you an idea of some of the changes which take place in the course of a stream. Fold a cardboard trough down to a glass dish. Pour water, a little at a time, on the sand bed at the top of the trough. As the water trickles down gradually, small grains of sand are carried into the glass dish. Why do the pebbles stay behind? Spill a lot of water at once at the head of the trough. Why are both sand and gravel now carried into the dish? The faster the speed of the stream, the heavier the load it carries. A rapidly moving stream can carry along large stones and even heavy boulders.

Equipment and Materials

- . . . sand
- . . . gravel
- . . . cardboard
- . . . glass dish

Reviewing the Concept

(Text pages 223–24)

Before You Go On. 1. a 2. b 3. a

Using What You Know. 1. The water is carrying soil. 2. Mountains, hills, and river banks. 3. By wind.

Section 2: ROCKS BREAK DOWN

(Text pages 224–28)

SUBCONCEPT

The expansion of freezing water breaks down rocks.

Children learn that when water freezes it expands. Through investigation, they infer that this force of expansion is great enough to split rocks and break down mountains.

Processes emphasized

Observation
Investigation (with design of experiment)
Hypothesizing
Theorizing
Prediction
Library research

Introducing the Concept

Count to ten. What do you think has happened in this time to the highest mountain you have ever seen? (It has changed slightly.) How do you think it has changed? Encourage hypotheses. Many changes in mountains occur so slowly we are not aware of them; other changes may occur very rapidly. Call attention to the picture on page 224. Where did the bits of rock near the bottom come from? A rock pile or rock slope is evidence that bits of rock have been broken off and the mountain is slowly being broken to pieces. Why do you think rocks in the rock slope are usually big and piled in disorder? Why do you think there are no plants on the rock slope? In answering both questions, children reason that these rocks have fallen recently.

What is strong enough to break down a great mountain?

Developing the Concept

Freezing water expands.

The investigation. As the investigation is being planned, ask: What do you think will happen? Most children know that the frozen water will be above the surface of the can. But, even so, it is well to encourage a wait-and-see attitude. If children are convinced, try adding to the investigation by asking: What do you think will happen if we seal the water in? Then fill an empty pint or quart milk carton to the brim with water. Close the flip-top securely and leave in a freezer overnight. Observe the next day. The expanding ice should have pushed up the lid.

Equipment and Materials

- . . . pint or quart cartons

Expansion of water as it turns to ice has great force.

Equipment and Materials

. . . plaster of Paris
. . . water
. . . rock sample with cracks

Widening the crack. While you are waiting for results of the investigation, return to the rock pile at the foot of the mountain. How do large rocks get broken off from mountains? If pupils suggest that ice expands enough to break rocks, ask: Shall we find out? Make a plaster of Paris block with a crack in it. Pour in water and set the block in the freezing compartment of a refrigerator. How will we know if ice can break a rock? (The crack becomes wider.) Children may bring in a rock sample with a crack in it. Try widening the crack by filling with water and freezing. You may need to do this many times, just as it happens on a mountain, before the rock will split.

Ice occupies a greater volume than water.

How water expands. When you heat water, do the molecules move faster or slower? When water becomes ice, the molecules slow down. But, as you saw in your investigation, water does contract until about 4° F. and then expands due to the way the atoms of oxygen and hydrogen arrange themselves in an ice crystal. Instead of continuing to contract, as most substances do, water expands. What do you think happens when the freezing water has no room to expand? Suggest that children read the text, and be prepared to compare it with the results of their investigations.

Extending the Concept

Equipment and Materials

. . . two glass bottles or jars
. . . plastic bag

The force of ice. Obtain two small glass bottles or jars with screw tops. Fill one jar to the top with water. Secure the tops carefully on both jars. Place the bottles in a small plastic bag and put in a freezer. After an hour examine both bottles. You should find that the water in one bottle has turned to ice and the bottle has cracked. Why did the bottle with the ice crack? Why didn't the empty bottle crack?

Glaciers—huge fields of ice. Encourage children to learn more about glaciers by doing library research. What causes glaciers? Why do glaciers move down a mountain? How fast do they move? How do glaciers help to break down a mountain?

Telling age by their shape. Can you tell the age of a mountain? Young mountains usually reveal their age by their sharp rugged peaks. Older mountains become smooth and rounded after many thousands of years of wearing down. Are the mountains pictured on pages 218 and 224 old or young? What are their names? (The Rockies.) Where in the United States would you find old mountains? (The East, especially.) What is the name of these mountains? (Appalachians.) Children will enjoy discussing how these and other mountain ranges differ.

(Text pages 227–28)

Reviewing the Concept

Before You Go On. 1. a. 2. a 3. a

Using What You Know. 1. Water contained in the milk expands and produces a force as it freezes. 2. Ice freezing and breaking pieces of rocks from the cliffs above the road.

Section 3: THE HEAT OF THE SUN

Children examine the effect of heating and cooling and investigate how plants can break down rock. They infer that the energy of the Sun and growing plants exert forces.

Introducing the Concept

You might try this: Hold a piece of dry shale (using tongs) in the hot flame of a gas burner or an alcohol lamp. After the rock becomes hot, plunge it into a can full of ice water. What happens to the rock? Why do bits of rock break off and settle to the bottom of the can?

How can just the heat of the sun split a rock?

When there has been enough discussion, you may want to suggest that the text may offer some ways to investigate how the sun can split rock (pages 228–30, up to **The Force of a Plant**).

Developing the Concept

Expanding and contracting. By planning the investigation described and pictured on page 228 and pictured on page 229, children will review the concept that air expands when heated and contracts when cooled. But what has this to do with breaking down rock?

Some wearing away of the Earth is the result of temperature change. As children read the section, they discover that rock can expand and contract. As the Sun heats rock during the day, the rock expands. The outside of the rock expands more than the inside. At night, as the rock cools, it begins to contract. In time, what do you think happens to the rock which has been continually heated and cooled? (It gets full of cracks and bits of rock begin to break off.) In a similar way, unequal expanding and contracting cause a mountain to break down, bit by bit, over a long time.

Coat several inflated balloons with a layer of shellac, thick tempera, or moistened detergent powder. When the coating is dry, release some air from the balloon. Why does the coating crack? (The balloon contracts.) What is another way of making a substance contract? (Cooling.) Some children, recalling their work with molecules, may say that the molecules contract. Their reasoning should be corrected, for molecules merely move farther apart when a substance expands and closer together when it contracts. Relate the expansion and contraction of rock in the heat of the day and the cool of the night.

The investigations. Have you ever thought a plant as it grows might have enough force to make a rock crack? Perhaps you have noticed small flowers or grass breaking through the pavement or sidewalk. Where do these plants come from? How can they grow and push their way through the concrete? Let two groups of children design the investigations on pages 231 and 232 before going on to the explanation in **The Force of a Plant** (page 230).

(Text pages 228–34)

SUBCONCEPT

The expansion and the contraction of rock, and the force of growing plants, help break down rock.

Equipment and Materials

. . . shale
. . . gas burner or alcohol lamp
. . . tongs
. . . can of ice water

Unequal expansion and contraction can break rocks.

Processes emphasized

Observation
Analysis of observations
Investigation (with design of experiment)
Hypothesizing
Theorizing
Measurement
Reporting

Equipment and Materials

. . . balloons
. . . shellac, or tempera, or detergent powder

Growing plants can break rocks.

Equipment and Materials

See text pages 231 and 232; also the Teacher's Manual for *Classroom Laboratory 4.*

In the first investigation did the sprouting seeds break the glass bottle? Did the seeds expand or contract? How do you know? Where do sprouting seeds get their force?

In the second investigation, why do you think the seeds were placed tightly between two pieces of glass? (To model a plant growing in a crack.) Why did the investigation suggest that you use a blotter? (Moisture.) What does a plant growing in the crack of a rock have instead of a blotter? (Soil.) In the investigation, rubber bands hold two pieces of glass together. What causes these pieces of glass to be pried apart? To measure the amount of prying, a count of the number of thicknesses of paper that can be inserted between the panes at different times is useful. Can you now explain how a plant may cause a rock to break?

Extending the Concept

Root hairs erode rock. Plant roots can erode rock surfaces. Scrape off some lichens which are growing on rock. Then obtain a sample of growing moss from a brick or stone. What do you notice attached to the plant roots? Why do rock particles flake off with the plants?

Equipment and Materials

- . . . empty milk carton
- . . . plaster of Paris
- . . . disposable mixing bowl or carton
- . . . bean seeds
- . . . paper towels
- . . . plastic bag
- . . . thermometer

Remove one side of an empty milk carton and place the carton on its side. Pour plaster of Paris into the carton to make a 1-inch-thick slab. Arrange sprouted lima beans or other seedlings on the hardened plaster top. Cover the seedlings with moist paper toweling or other humid container. Place the carton in a plastic bag. After a week, open the plastic bag and lift off a few seedlings. What has happened to the surface of the plaster where the seedlings were growing? Suggest that children draw and describe what they see.

The temperature of rock. Find a huge rock or rock slab or the bare brick or stone wall of a city building. Feel it and measure its temperature in full sunshine daily at the same hour for several days. Why does the rock feel warm even when the Sun sinks or has dropped out of sight? In the early morning, is the rock temperature higher or lower than the air temperature? How do you explain the difference in temperature?

(*Text pages 233–34*)

Reviewing the Concept

Before You Go On. 1. a 2. a 3. a

Using What You Know. 1. Temperature changes cause unequal forces to crack the rock. 2. Water. 3. The rails would bend; steel expands in warm weather.

(*Text pages 234–40*)

SUBCONCEPT

Land worn down in one place is built up in another.

Section 4: BUILDING UP THE LAND

Children gain further evidence that the Earth's surface is constantly changing and that land is built up when slowing water drops its load of sediment.

Introducing the Concept

Recall the model river in the investigation on page 221. We are going to model a river in another way. In a large jar place 2 inches of sand, soil, and gravel. Add water until the jar is about three quarters full. Then bend a piece of heavy foil into a long trough. Hold the foil trough at an angle over a basin or bucket. Shake the large jar until particles have mixed well with the water. Pour part of the mixture into the upper end of the trough. Why are few or no soil particles dropped as the water flows rapidly down the trough?

Now crumple the foil and then reshape into a trough. Again shake the jar and pour some water into the upper end of the trough. This time why are some soil particles dropped and retained in the "stream bed"? How could you change or bend your foil "stream" to catch or build up still more soil?

Flatten the trough at the end close to the basin. As you pour the water, soil particles build up at the flattened place in the trough. Why does this happen?

Relate this introductory demonstration to earlier work in the unit and to reading of page 234. Now there are other questions about our changing Earth to be explored.

Does a river build up soil when it goes swiftly or slowly? Where will the soil go which travels down a river? How is there room in the sea for all of the soil which is carried down? If land is continually worn down, why hasn't land long ago been drowned in the sea?

Can you suggest other questions to add to this list?

The Earth's surface is always changing.

Processes emphasized

Development of models
Analysis of observation of models
Hypothesizing
Theorizing
Library research
Prediction

Equipment and Materials

. . . sand
. . . soil (loam or topsoil)
. . . gravel
. . . large jar
. . . heavy foil
. . . bucket or basin

Developing the Concept

The investigation. Can you guess why soil builds up in some places but not in others? After children have had a chance to state their hypotheses, let them design the investigation on page 235.

As you stirred the water in the jar very fast, what did you notice? Did the soil particles move rapidly, too? What happened to the soil particles when you stopped stirring? How does this help you explain why slow-moving water in a stream can build up land?

Slow-moving water can build up land.

Equipment and Materials

See text page 235; also the Teacher's Manual for *Classroom Laboratory 4.*

Flooding a valley. No doubt you have read about big floods in the newspapers. As large amounts of rain fall, or snow on the top of high mountains begins to melt, rivers become flooded. They cannot hold all of the water. Water rises and overflows its banks.

Flooding rivers build up soil in valleys.

Look at the pictures on page 237. What is happening to the river? As water floods over its banks, will the water move rapidly or slowly? What happens to the soil? How are valleys built up? Why do you find more farms in valleys than on hills? Reading of **Down in the Valley** (pages 234, 236–37) will clarify your hypotheses.

Where streams open into the ocean. Call attention to the mouth of the Mississippi River (page 238). What is happening? Is the water moving rapidly or slowly? What do you notice about the land? How does the

As water slows down at the mouth of a river, it deposits soil.

investigation on page 235 help to explain what you see in the picture? What clues did you find in the introduction of this section which will help support this statement: As water slows down, it deposits soil at the mouth of a river.

Children show evidence of their understanding that the Earth is constantly changing.

Gaining understanding. By the end of the section, children should be able to express in their own words these understandings:

The faster water flows, the more material it can move along. The slower it flows, the less it can carry.

Land is built up in the valleys, even as it is torn down in the mountains.

When a valley is flooded, water drops much of its load of soil.

At the mouth of a river, water usually slows down as it meets the sea.

Soil is deposited at the mouth of a river and the land is built up.

Extending the Concept

Building up fertile soil. Why is the soil which is deposited near the river's mouth considered excellent for raising crops? A visit to the library will offer interesting information about examples of fertile delta soils. Fine crops are raised at the mouth of the Rhine River in Germany and the Nile River in Egypt. What other rich delta lands can you name?

Hillside farming. How do people who live in hill country catch soil for farming? You have learned how slowing water can build land. People in lands that are high and have little rainfall have learned how to use this idea to catch and hold both soil and water in terraces. To understand how these terraces work, make a pie-plate-sized model of a low rounded hill. Sprinkle the hill with "rain" until some tiny gullies begin to appear. Place a row of fine pebbles at right angles to the gully near the top of the hill. Farther down place other rows of pebbles, shored up with twigs or matchsticks. Sprinkle the hill again with water. Why does fine soil begin to accumulate in tiny terraces behind each row of stones? Can you reason why hillside terraces take years to build and moments to ruin? In what parts of the world are farmers forced to depend on hillside terraces? Are there areas in your own state or local area which have to catch soil for farming? Investigate these questions in references and prepare a report, illustrated if possible.

(*Text pages 239–40*)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. a

Using What You Know. 1. Yes; the cliffs at the left and the flat land along the bank. 2. Rich topsoil has been washed from hills and mountains and deposited on farmlands in the valley. 3. a. Yes; soil from mountaintops builds up land in valleys and at river mouths. b. No; heavier soil and rocks need more force to move them.

Section 5: HOLDING LAND AND WATER

(Text pages 240–44)

Children investigate the function of plants in holding soil.

SUBCONCEPT
Plants reduce erosion.

Introducing the Concept

Recall how water looks in a stream after a rain. Are all streams muddy or are some clearer than others? How can we show it? Line three separate shoe boxes with aluminum foil. Cut a slot at one end of each box. Fold some foil into each slot in the form of a downspout. Fill each box with an equal amount of soil. Leave the soil in one box bare. Cover the soil in the second box with grass sod. Place a cover of leaves or leaf mold over the soil in the third box. Elevate all three boxes equally so that the downspouts can feed into a basin. Using a sprinkler, cover each box with an equal amount of water. Which box produces a muddy stream of water? Why is the water muddy? How does the water from the other spouts look? How do you explain the differences in the amount of soil coloring the water?

How do plants and leaves keep water from carrying soil away?

Equipment and Materials

. . . three shoe boxes or similar containers
. . . foil
. . . soil
. . . sod
. . . leaves, or leaf mold
. . . basin
. . . sprinkler

Developing the Concept

Children infer that plant roots hold soil.

Plants as soil builders. If possible, plan a class trip to an area in your community where soil has been washed away because of the lack of trees, plants, or leaves. What has happened to the soil? What might have prevented erosion (washing away of the soil)? Why are plants such good soil holders? The picture of the geranium plant (text page 241) is an excellent example of how roots hold soil. Encourage children to plan an investigation to observe the network of tiny root hairs which holds soil together. They should use a hand lens to make a rough count of the root hairs on their geranium or other plant. Would you say that a large part of a plant—perhaps the largest—is to be found below ground? How much soil do tiny roots and root hairs hold? The text suggests that you take all the soil off the roots of a few weeds. Can you think of a way to measure the amount of soil you take off? If washing in water is suggested, the plant may be dunked in a known weight of water and the difference compared. Or the water can be evaporated and the soil remaining weighed.

Processes emphasized

Observation
Analysis of observations
Investigation (model-building)
Hypothesizing
Theorizing
Prediction

Trees hold the soil with their roots and they provide cover.

The investigation. Can you explain why forest soil does not easily wash away? You can, of course, correctly answer that like small plants trees have a massed network of roots and root hairs which hold soil together, so that rain does not wash it away.

In what other way do trees prevent soil from washing away? What does the term *cover* mean? After children read pages 240 and 241, they discover that tree leaves act as a cover and break the fall of rain. Volunteers, or several class groups if you have enough equipment, may set up and demonstrate the investigation on page 242. To see how leaves act as a cover, observe, the next time it rains, how the drops fall hard upon the leaves of a tree before dripping gently to the ground. Even in the fall and winter, leaves help to hold soil by breaking the force of the raindrops that fall to the Earth. How does a cover of leaves act like a sponge, keeping soil from washing away?

Cover crops hold soil.

Grass as a cover. Is grass planted around your home? Around your school? On your way to school did you notice grass planted in other yards or along the street? How is grass such a good cover?

Bring into the classroom a small clump of grass. Observe the grass roots closely. What do you notice? Are there many, many tiny roots or are there several big roots? Why are the tiny roots better for holding surface soil?

After a rainfall, look for signs of soil splashed against the foundation or lower framework of a building. Why are there more splash marks next to a building where the ground is bare than next to a building where grass or shrubs grow close?

Read text page 243. Can you explain what has happened in the picture at the top of the page? What could have been done to prevent the loss of so much soil?

Extending the Concept

Where do you find vegetation? Does your geography textbook include vegetation maps? If so, can you predict the areas in which streams are likely to run muddy after a rain? Where will they be clear? What clues about the amount of plant life do the maps give to support your predictions?

Pedestal erosion. The fine small particles of topsoil, the best for growing plants, are the first to be carried off by water. Sometimes such particles are pinned down and held not only by leaves but by heavier pebbles and stones. Where erosion skims off the topsoil, you are likely to find tiny pedestals of soil held in place by heavier material. These little piers of loose soil capped by a hard surface are model replicas of the great sandstone buttes and mesas of the Southwest. They may be simulated as suggested by the additional text investigation on page 242. If you did not do the investigation earlier, you may wish to do it now. Bottle caps may be substituted for pennies.

(*Text page 244*)

Reviewing the Concept

Before You Go On. **1.** b **2.** a **3.** a

Using What You Know. **1. a.** Yes; good soil is necessary for growth of good crops; only the top few inches contain decayed matter (humus) rich in minerals. **b.** No; roots hold the soil. **c.** Yes; they break the force of raindrops that erode soil. **2.** Yes; as a soil cover. **3.** The farmer should plow across the hill, not up and down; the furrows hold rain and soil, keeping it from being washed away.

Section 6: THE RISING MOUNTAINS

Children discover that several forces interact to cause upward shifts in the Earth's crust.

(Text pages 245–48)

SUBCONCEPT

Pressures on and in the Earth cause mountains to rise.

Processes emphasized

Theorizing
Building of models
Observation
Analysis of observations
Prediction
Library research
Reporting

Introducing the Concept

Draw the following road sign on the board:

DANGER
MEN AT WORK

In how many ways can we change the last line to show forces at work continually changing the Earth's surface? (Among the first suggestions are likely to be *Sun, plants, water.*) What other forces? (*Wind, animals.*) What happens to all of the rock and soil carried down from hills and mountains? Since mountains and hills are constantly being worn down why can we still see hills and mountains towering high into the sky? Can you think of any way new mountains can be built? Children will investigate these questions in this section:

How does an understanding of the inside of the Earth help explain why mountains rise? Are mountains always rising? Why do the main mountain ranges of North America run north and south?

Developing the Concept

The pressure of sediment may cause mountains to rise.

Rising mountains. What happens to all the soil carried down to the sea? Think of the weight of soil that is deposited on the sea bottom. Scientists believe that it is so great that it makes the Earth's crust change.

How could a pile of soil in the ocean change the crust—push up a mountain—for example? To see for yourself, balance a pan of water opposite a pan of soil. A platform balance or pan scales can be used. Suppose the water represents an ocean; the pile of soil, a range of mountains. If you shift some sand into the "sea," why does the mountain pan rise?

Equipment and Materials

. . . two pans
. . . platform balance or pan scales
. . . soil
. . . map or globe

Look at a map or globe. Do you notice that many great mountain ranges of the world seem to be near a coastline? The Appalachians, running from Maine to Georgia, are along which coast? (The Atlantic.) These mountains are old mountains (how do you know?) and may have risen because of sediment deposited ages ago. What great ranges have risen along the Pacific coast? These are young mountains (how do you know?) and may have risen because of more recent deposits of sediment. This does not mean, though, that mountains cannot rise somewhere else; it is only one hypothesis. Heat within the Earth may cause mountains to rise.

The Earth's rocks deep below the crust flow like a liquid.

Inside the Earth. Do you think that you are standing on rock solid all the way to the center of the Earth? How could mountains push up if you were? As children read the section, call attention to the picture

Pressure on the molten liquid within the Earth causes the crust to rise, forming mountains.

Equipment and Materials

. . . tube of toothpaste (partly filled)

. . . modeling clay

at the top of page 246. What does this picture show? (Molten rock that flows from beneath the solid crust of the Earth.) It flows or oozes under pressure. Emphasize the function of heat in causing internal pressure.

Two models of mountain building. Page 246 suggests that a partly filled tube of toothpaste, when squeezed, is a model of the flow of material below the Earth's surface. Hold up a tube of paste and select a volunteer to squeeze one end. What happens at the other end of the tube? Something like this also happens to our Earth. As the land sediment presses down in one place, the land may rise in another.

To illustrate further that the Earth is not solid but that its surface rises and falls under pressure, hand out balls of modeling clay. Ask children to squeeze the clay in their hands. What happens? (Ridges of clay rise between the fingers.) How are these ridges models of how a mountain may be built up?

Extending the Concept

The earth below the sea. Try to imagine a great ocean with all of the water out. Perhaps you have seen the bottom of a pond or reservoir being drained. What do you think it looks like on the bottom of the seas? Your librarian can help you find books about oceanography, the study of the sea. You will find that the ocean floor has hills and valleys and mountain ranges just as you find on land. Is the rise and fall in these valleys and mountains caused by the same pressures which change the land about us? Report your findings to the class.

(*Text page 248*)

Reviewing the Concept

Before You Go On. 1. a 2. b 3. a

Using What You Know. 1. It causes rocks to flow from a place where the pressure is great to one where the pressure is less. 2. Yes; mountains are worn down and sediments form; sediments become rocks and may rise to form mountains. Then these are worn down again.

(*Text pages 249–53*)

CONCEPTUAL SCHEME

Living things are in constant change.

UNIT CONCEPT

The environment is in constant change.

How is land worn down? How is land built up?

Section 7: THE MAIN CONCEPT: THE EARTH IS CHANGING

Children gain a fuller understanding of the concept of change. As conditions on the Earth change from day to day and from season to season, the agents of erosion break down mountains and other forces build them up.

CONCEPT SUMMARY

Land balance. On the chalkboard make two columns: LAND BUILT UP and LAND WORN DOWN. Encourage children to contribute ideas for both columns. How is land built up? In what ways is land worn down? What land changes can you add which were not mentioned in the text?

What are some signs of change in the Earth's surface?

Change all about you. How many kinds of change in the Earth's surface were mentioned in your text? Which of these changes can you see from the classroom window? around the school yard? around your yard at home? Signs of change in the Earth's surface are everywhere.

In a series of pictures, illustrate kinds of change in the Earth's surface. Arrange the pictures in sequence on a roll of shelf paper. Use rolling pins or doweling rods as spools to wind or unwind the "film" through two slots in a cardboard carton. Children will enjoy narrating their own "sound track."

How does a river's speed change the Earth's surface?

The speed of a river. Measure the speed of a river. Station one child on the bank near the river. Another child 100 feet upstream tosses in a stick. How long does the stick take to drift to the point where the first child is standing? Using the distance traveled by the stick and the time taken, compute how fast the water is moving. How does the speed of moving water affect changes in the Earth's surface?

How does a river cut through soil?

Measuring the erosion of a river. Estimate the depth of the cut a stream has made into the surface of the Earth. First gauge the depth of the stream by dropping a weighted string to the stream bed. Record the length of the wet part of the string. Next find out and record the distance between the level of the river and the top of the valley walls. Add the two measurements to determine the depth of the cut. What has happened to the soil?

How can erosion by a river be controlled?

Control of erosion. Examine a river bank to note signs of erosion. Where is exposed soil being washed away by the current? Have rocks or other materials been placed on the banks to slow up the cutting action of the water? Are plants being used to slow erosion of the soil? Look for places where rainwater running down hills has cut gullies. What should be done?

Which moves more soil: slow-moving or rapid-moving rivers?

Slow and rapid motion. Note the appearance of water in a stream. Is the water clear or muddy? If possible, collect one sample of water when the river is low, and another when the river is flooding. Let the jars stand undisturbed for a few days. Compare the amount of deposit in the bottoms of the two jars. Is there evidence that rapidly moving flood water carries more soil?

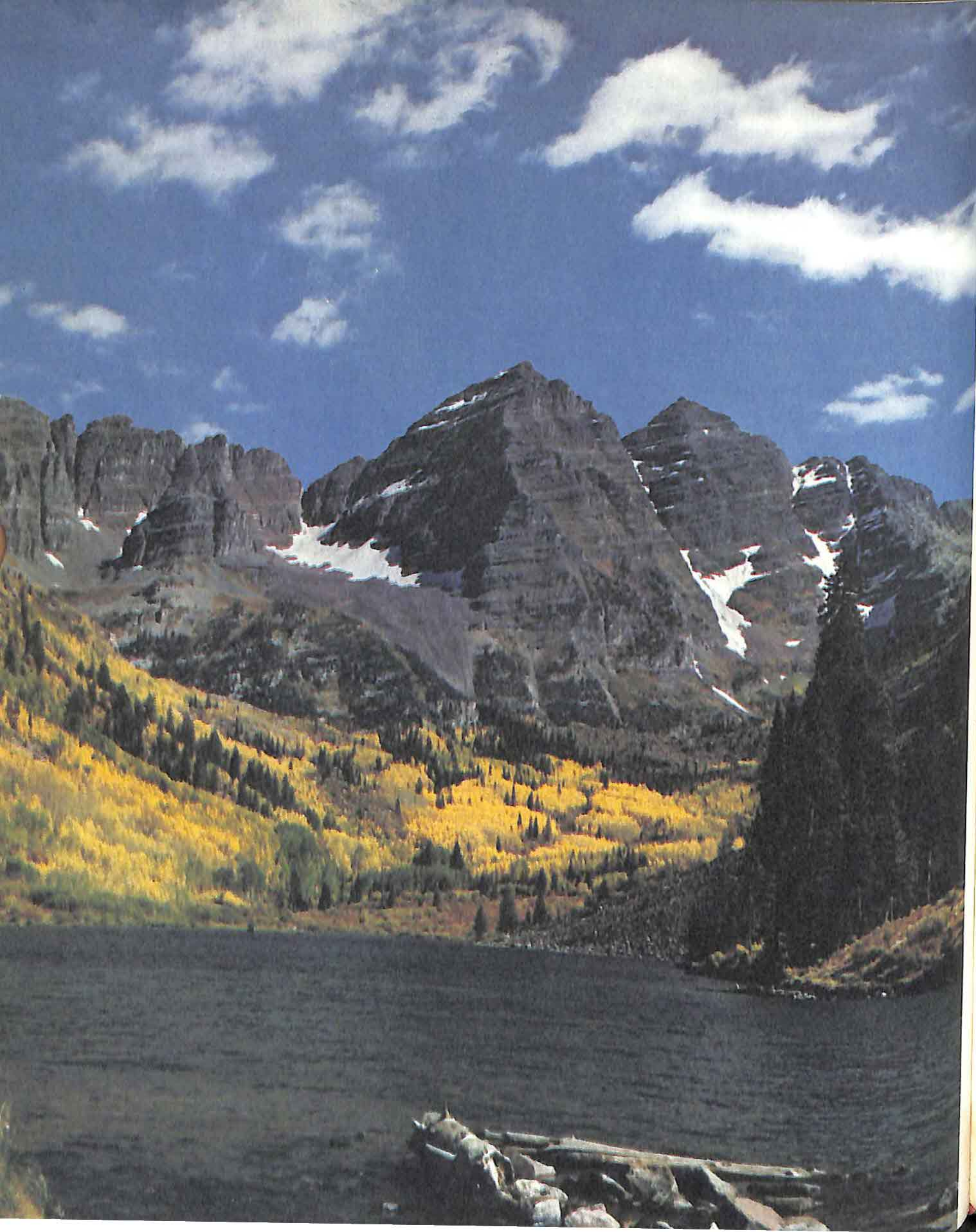
What kinds of environment do the Earth's changes provide for living things?

Changing plant and animal life. What kind of plant life do you find along a stream? in a valley? on a rocky hillside? in a sandy, dry area? What kinds of animals live with these plants because they provide food, cover, and places for animal homes? The changing Earth environment gives an opportunity for children to draw together concepts of interdependence from earlier units and see relationships more clearly. Living things are in constant change; the environment is in constant change.

(*Text pages 250–53*)

FIXING THE MAIN CONCEPTS

Testing Yourself. 1. a 2. a 3. a 4. b 5. a 6. b 7. a 8. b 9. b 10. b



UNIT SEVEN

THE TRAVELS OF A HANDFUL OF SOIL

These are the Rocky Mountains. That high peak reaches about one half mile above the lake. The mountains are made of hard rock.

They look as if they would never change, don't they? They look as if they had always been there and would always be there.

But they have not always been there. They will not always be there. In fact, they are breaking down now.

How can this be? The Earth is always changing. Let us see how. We begin not with a mountain, but with a handful of soil.

1. The Moving Land

Here is a handful of soil. ■ Looking at it, you would not think of soil as a traveler, would you? Yet soil does travel, and sometimes, for amazing distances.

How does soil travel? Where does it travel to? Try the investigation on the opposite page and see for yourself.

A Model River

The pile of sand in the investigation became a model, a model of a river. The model river is very small compared to a real river. Yet it does show what can happen in a real river.

■

The model river shows that sand can be carried along by running water. At the bottom of the model hill is a pile of sand that has been carried down by the water. You may even have been able to see sand being carried along in the moving water.

This is not really surprising, is it? You know that running water has energy and can make things move. Running water can carry sand along. It can also carry soil. If it is moving fast enough, running water can carry stones and even boulders along. You may have seen how water carries soil after a rain. Perhaps you have seen it carry pebbles, too.

AN INVESTIGATION
into How Water Moves Land

Needed: an empty aquarium, coarse sand, a sprinkling can filled with water

Pile the sand at one end of the aquarium to make a hill. ■ Make a groove down the hill an inch or two deep. Make a clear area at the bottom of the hill, on the floor of the aquarium.

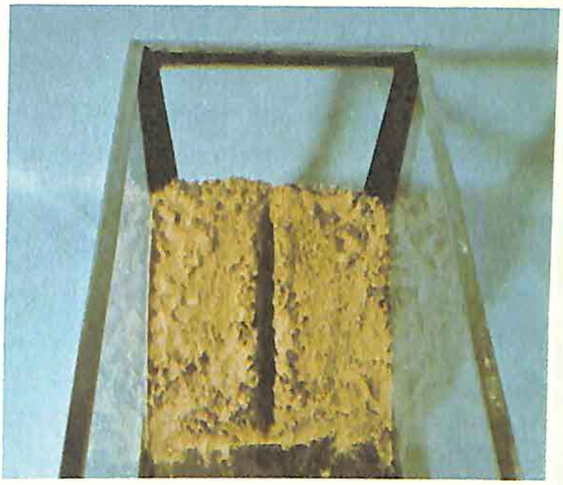
Take the watering can and sprinkle water gently on the hill to make "rain." Let water run down the groove so as to make a stream flowing down the hillside. ●

What happens to some of the sand that the water flows over? Where does that sand go?

Here is what happened on one trial. ▲

Additional Investigation: Is the water flowing fast or slow when it is carrying sand along?

Is the water flowing fast or slow when it drops the sand?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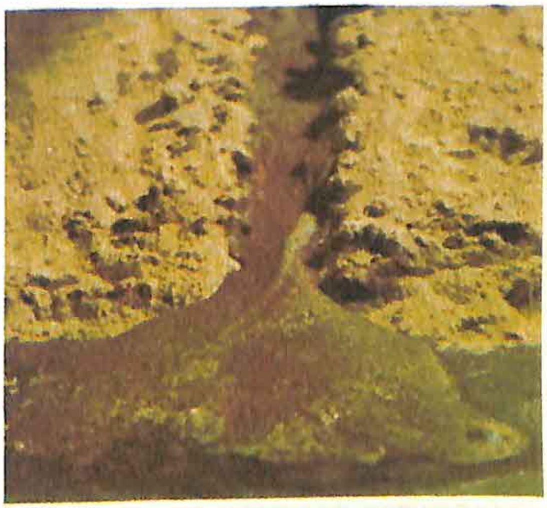
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Look at this real river, keeping in mind what happened in the model river. ■ Can you imagine what happens to the soil around this river when it rains?

The rain washes the soil into the river. When it rains hard, much soil is washed into the river. Stones fall in, too. The soil and stones are carried along by the running water. See how muddy this river is. ● The water is muddy because it is carrying much soil. Some of this soil was washed into the river not far from here. Some of the soil entered the river hundreds of miles away and has been carried down. It is still traveling. It will keep on traveling until the river moves so slowly that the soil drops to the bed of the river.

How does soil travel? In running water. Where does it travel to? Wherever the water travels. What will happen to it? We shall see.

The land that appears so quiet and unmoving is really moving, isn't it? The handful of soil you pick up one day may be washed down a river later on. It may even travel to the bottom of the sea.

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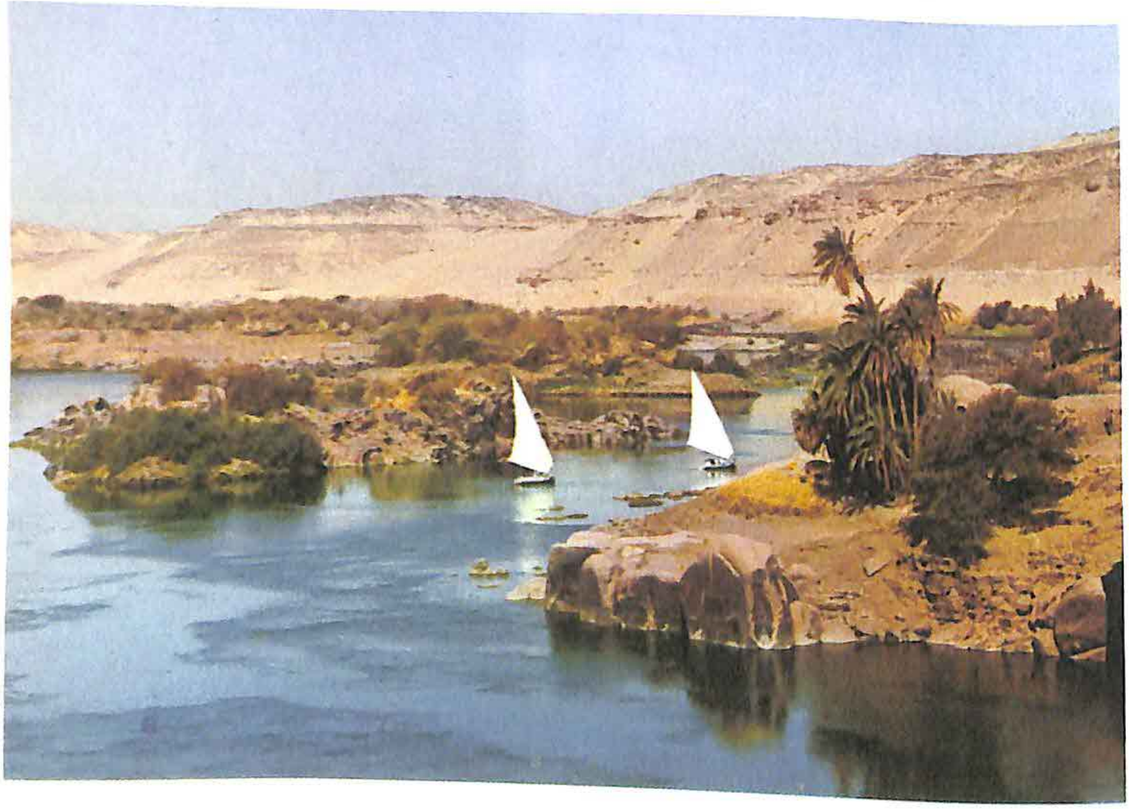


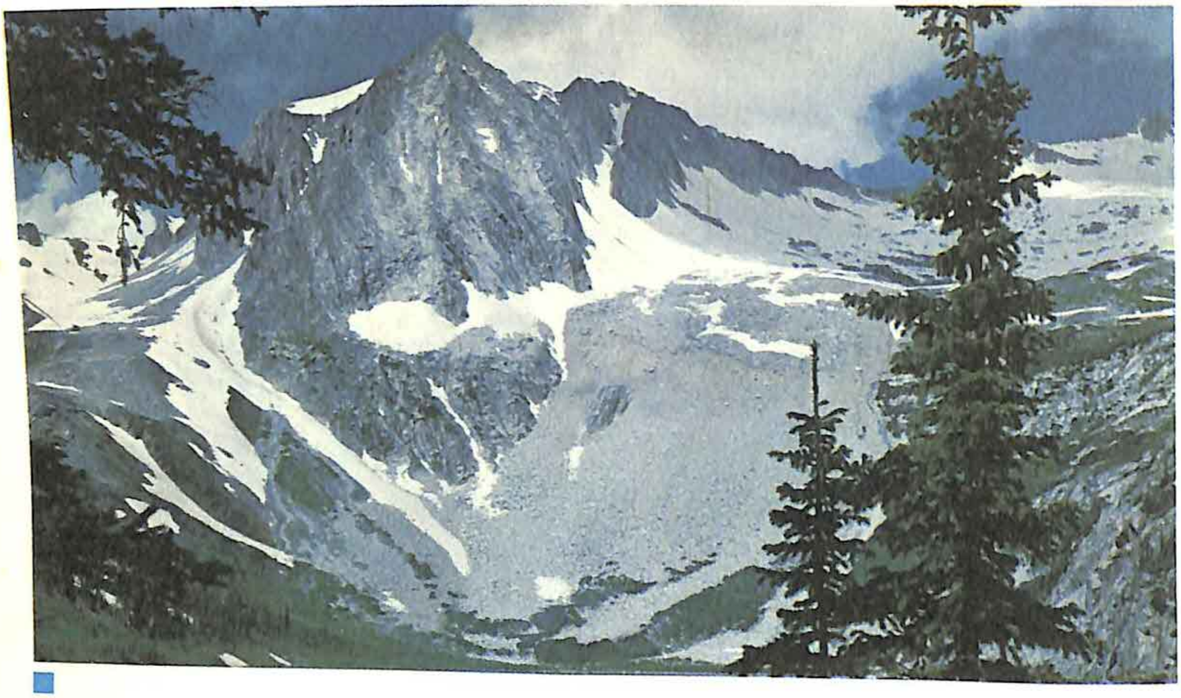
BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Running water can carry soil because it has
   a. energy　　b. wetness
2. The faster water runs, the
   a. less soil it can carry　　b. more soil it can carry
3. The faster water travels, the
   a. larger the stones it can carry
   b. smaller the stones it can carry

USING WHAT YOU KNOW 1. What does it mean when the water of a river is muddy?

2. Where do the soil and rock that are carried by a river come from?

3. What is another way in which soil may travel?



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ON YOUR OWN Suppose that a river is carrying along heavy particles, as well as light particles of soil and sand. What do you think will happen to the particles if the water slows down?

2. Rocks Break Down

Rain can wash soil away. It can wash small stones away as well. Streams and rivers may carry small stones and soil away, but the big rocks are left behind. Rain cannot carry away a mountain of rock.

Yet the big rocks, even the mountains of rock, are being moved.

Look at this evidence. Here is a photograph of a mountain in Colorado. ■ Like all mountains, it is made of rock. Observe the pile of material heaped up against the mountain. What do you suppose it is? How did it get there? The material piled against the mountain is bits of broken rock. Bits of rock have broken off the mountain and have fallen down its slopes. The mountain is being broken to pieces.

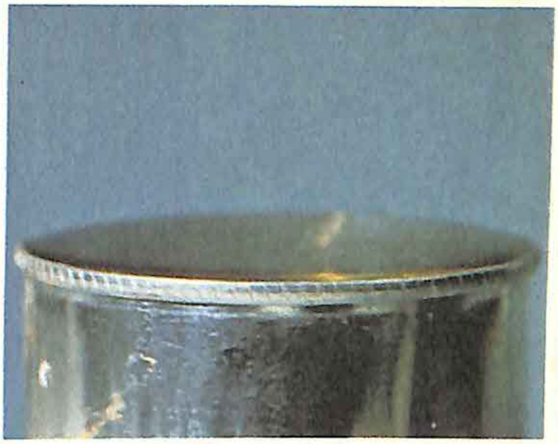
What could be strong enough to break down a mountain? The investigation on the opposite page will help you to find out.

AN INVESTIGATION into Freezing Water

Needed: an empty can with its top removed, a freezer or refrigerator, water

Fill the can with water so that the surface of the water is just level with the top of the can. ■

Place the can of water in the freezer, or in the freezing compartment of the refrigerator. ●



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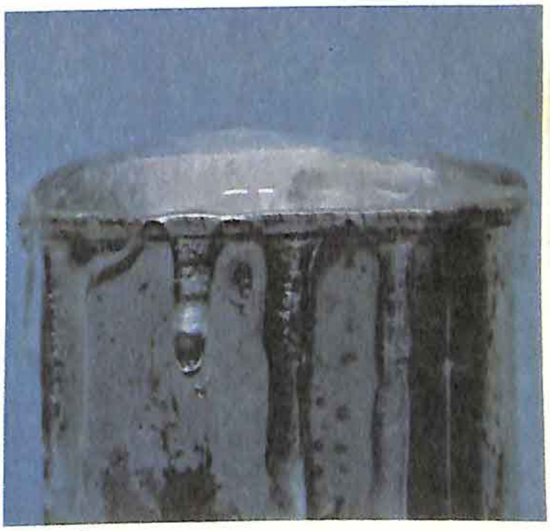
Freeze the water. As the water becomes ice, what happens to the room it takes up?

Here is what happened in one trial. ▲ How do you explain what happened?



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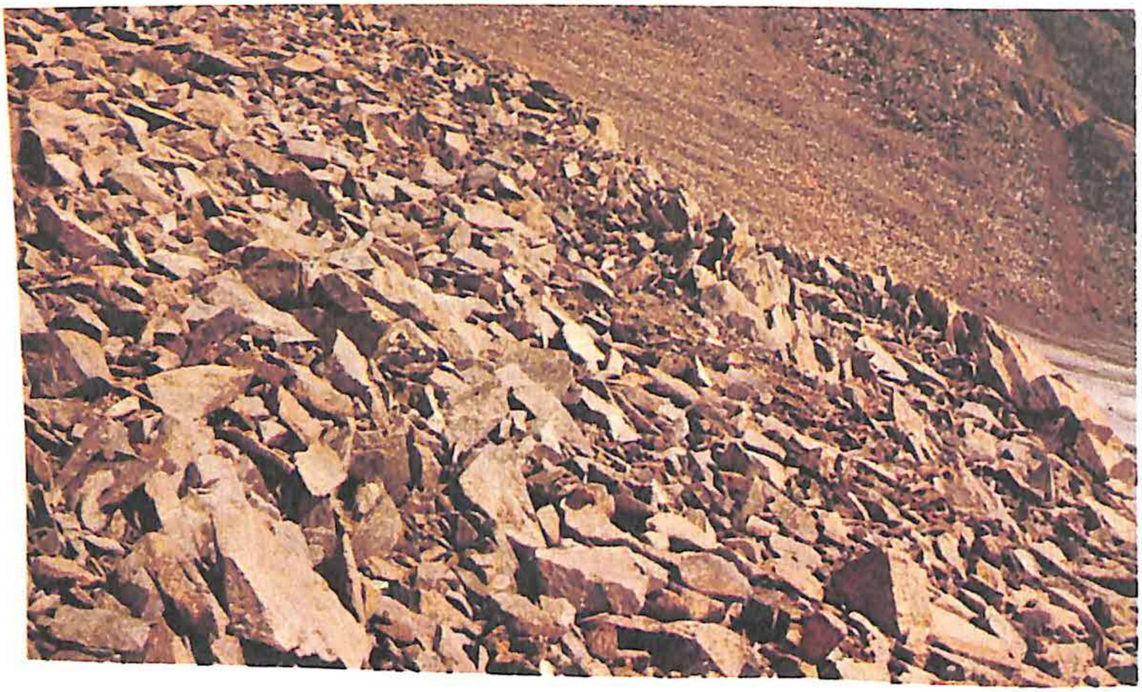

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The Force of Ice

When water freezes, it takes up more room. In other words, it expands. When a quart of water freezes, it expands to make more than a quart of ice.

Suppose that freezing water is prevented from expanding? Suppose that freezing water is in a space where there is no room to expand? In that case, the water produces a tremendous **force** as it turns to ice. The force made as water turns to ice is great enough to split rock!

When rain falls on rock, water may run into cracks in the rock. If the water freezes (perhaps during a cold night), it expands in the crack. We know that, as water freezes, the expansion can produce a great force. The force of freezing water widens the crack a little. ●

This can happen again and again. It rains. Water flows into a crack in the rock. It gets cold and the water freezes. As it freezes, the water expands. The crack in the rock gets wider. At last the crack gets so wide that the rock splits. The piece that breaks off may tumble down the side of the mountain. Along with other pieces it makes a heap at the bottom. These pieces may be split again and again into still smaller pieces. They may be carried away by running water.

Look at this close view of the heap of rocks piled against the side of a mountain. ■ You can see that there are large pieces of rock and smaller pieces. Most of them have sharp edges. Freezing water helped make this heap. The next time it rains, water rushing down the mountain will carry smaller pieces away. These bits of rock will become soil.

●

Soil may be carried away by running water. Small rocks may be carried away by running water. Big rocks, even mountains of rock, may be broken down into small pieces by freezing water. Then they may be carried away by water, too.

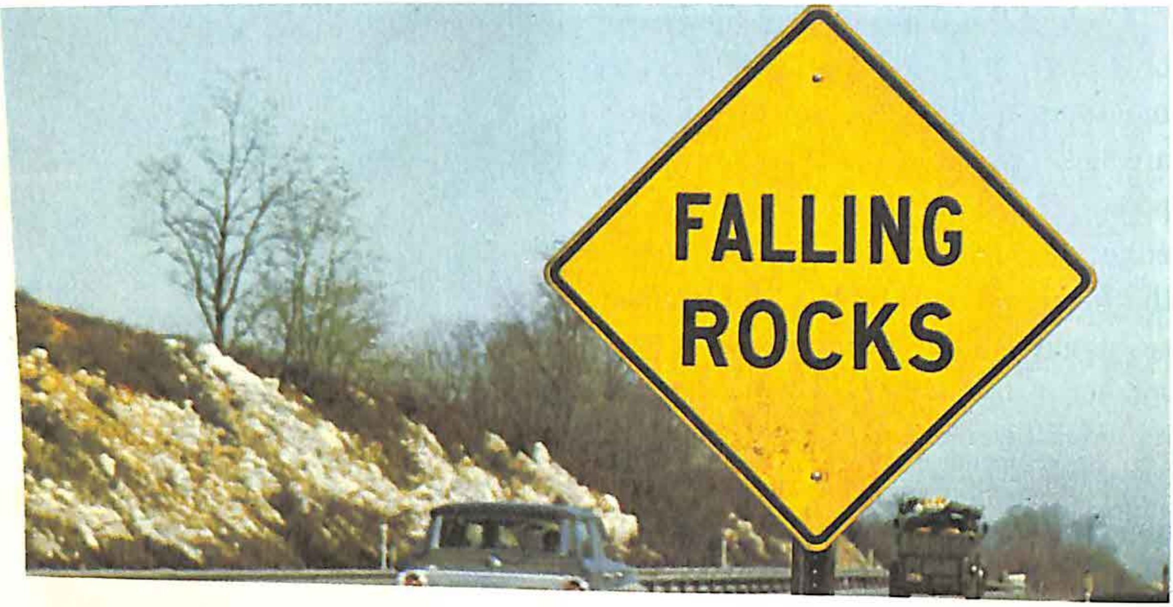
BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Freezing water
   a. expands b. contracts
2. When water gets into a crack in a rock and freezes, the rock may
   a. split b. pull together
3. As a mountain breaks down, its rock
   a. is carried away b. piles up on the top

USING WHAT YOU KNOW

1. A bottle of milk is left outside on a very cold winter day. The milk freezes. The bottle breaks. Can you tell why?



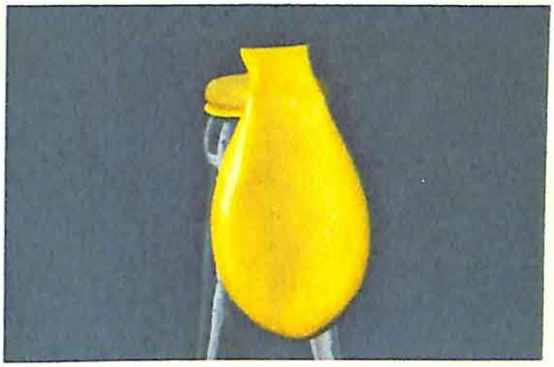
2. This sign is seen by the side of a road cut through rock. What could cause the rock to fall?

ON YOUR OWN Does the temperature sometimes go below freezing, where you live? See if you can find some places where freezing water has done its work on sidewalks.

3. The Heat of the Sun

Have you ever put your bare foot on a sidewalk on a hot day and found that the sidewalk was hot enough to burn your foot? The sidewalk has been heated by the Sun, of course. Bare rock can get very hot when heated by the Sun, too. This helps to break down rock. Let us see how.

You may have done this investigation. ■ If you have, you will remember that when the bottle is heated, the balloon gets bigger. The balloon gets bigger because the air in the bottle expands when heated. Then, as the air in the bottle cools, the air gets smaller, or contracts. As the air contracts, the balloon gets smaller again. Air expands when heated and contracts when cooled.



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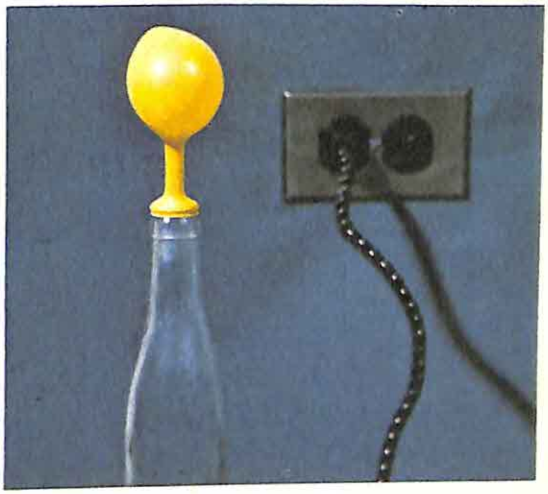

Here is another example. Heat makes the liquid inside a thermometer rise. This happens because the liquid expands as it is heated and rises inside the tube. When the thermometer is put in a cooler place, the liquid becomes cooler and contracts. As the liquid contracts, it takes up less room and goes down in the tube.

Most substances expand when heated and contract when cooled. This is also true of rocks. Rocks expand when heated and contract when cooled. This helps to break down rocks. Let us see how.

During the day, the rays of the Sun heat a rock. The outside of the rock becomes hot, but the inside does not become hot. As this happens, the outside of the rock expands. At night, the rock becomes cool again, and its outside contracts. Day after day, and night after night, the surface of the rock expands and contracts, expands and contracts. The surface of the rock peels off.● The surface that has been heated and cooled breaks off in layers. This happens especially when there is a large difference between the heating and cooling.

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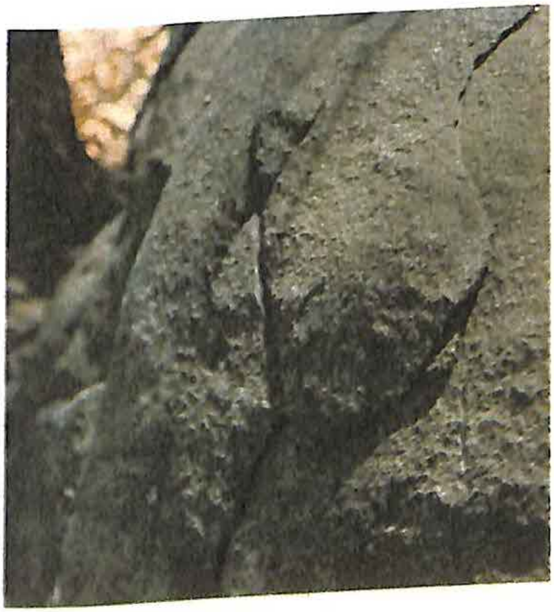

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In time, the peeled-off pieces of rock break down still more. They may be carried away by running water. The heat of the Sun then goes to work on the fresh surface of rock that has been laid bare.

So the Sun breaks down rocks by making them expand. It does more, however. The Sun helps plants to break down rocks. How can a little plant break down hard rock? The investigations on the next two pages will help you to find out.

The Force of a Plant

Seeds swell as they soak up water. They expand, and they can push with great force against anything that holds them in. Then, as seeds grow, they develop stems and roots. The roots push out against anything holding them in.

Imagine some seeds falling into a small crack in a rock. In the crack there is a bit of soil. Perhaps wind carried the soil there or water brought it there. When rain comes, the seeds take in water. They expand. They sprout. Their roots dig into the bit of soil and spread into every part of the crack, pushing against the rock. As the plant grows, it forces the crack just a little wider. ■ In the winter, water may freeze in the crack and expand and widen the crack still more.

You see, then, that plants can break down rock, helped by the Sun from which they get the energy to grow. The Sun's heat can break down rock by making it expand again and again. Water can break down rock as it seeps into cracks and then freezes and expands.

Water, Sun, plants, all working together, can break down mountains. It takes time, of course. It takes millions of years. But this breaking down of rock and carrying away of soil has been going on for a good many millions of years, and it will continue.

AN INVESTIGATION into the Force of Sprouting Seeds

Needed: a small bottle and a cork to fit it, enough bean seeds to fill the bottle, a paper bag

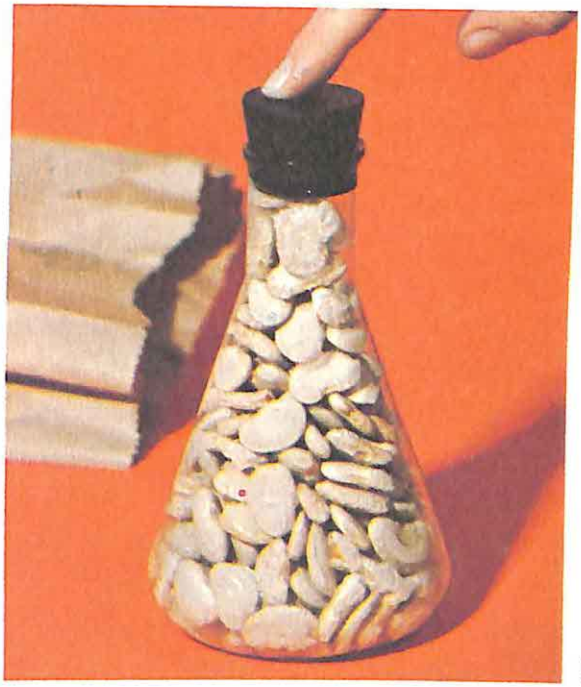
Fill the bottle up to the neck with the dry bean seeds. Add enough water to just cover the beans. Put the cork in. ■

Put the bottle in the paper bag to keep the seeds dark. Seeds sprout best in the dark. In about 3 or 4 days the seeds will have sprouted.

What happens to cork and bottle?

Here is what happened in one trial. ●

Now try the investigation on the next page.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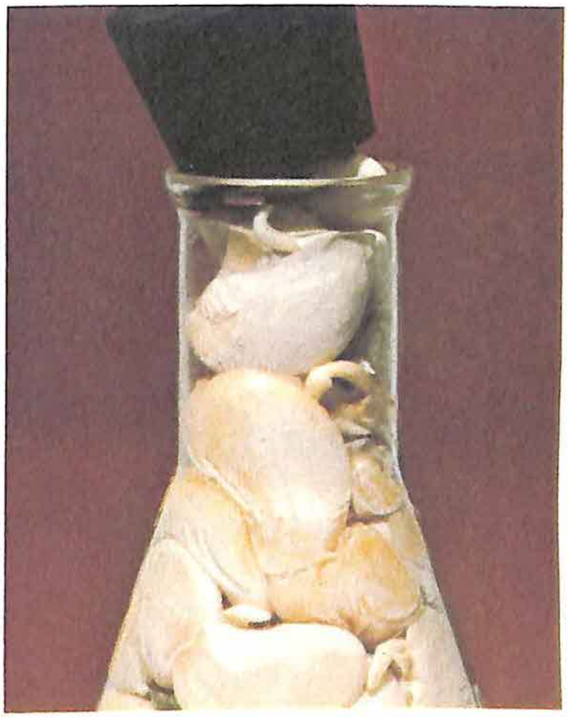
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AN INVESTIGATION into What Happens When Plants Grow

Needed: two pieces of glass, a piece of blotter, rubber bands, some radish seeds

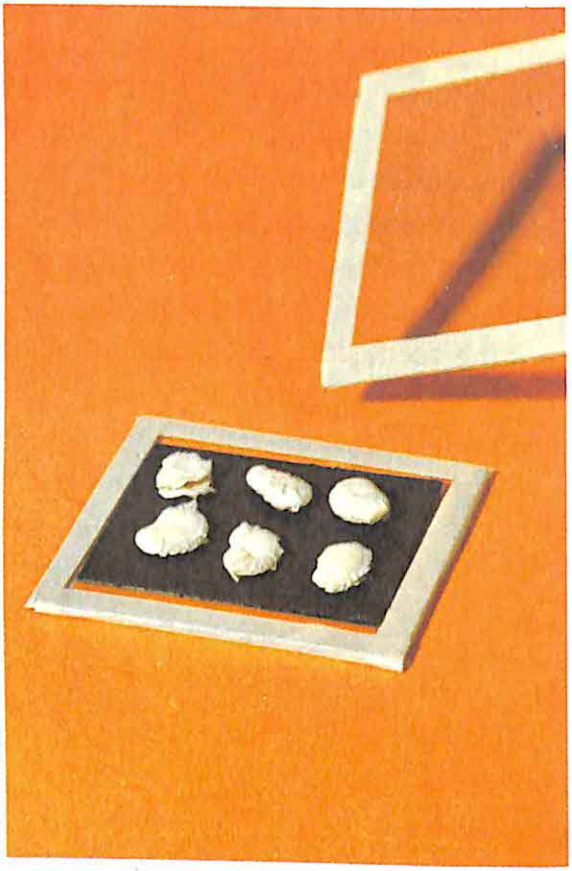
Put the blotter on a piece of glass. Put some seeds on the blotter.

Place the second piece of glass on top of the seeds. ■ Put rubber bands around the two pieces of glass. This will hold them together. The seeds are now between two pieces of glass.

Stand the glass "sandwich" in a pan that has a little water in the bottom. ●

Watch the roots. Notice how they push everywhere and pry the two pieces of glass apart. What would happen if they grew into a crack in a rock?

Here is what happened in one trial. ▲ Now turn back and read "The Force of a Plant" on page 230.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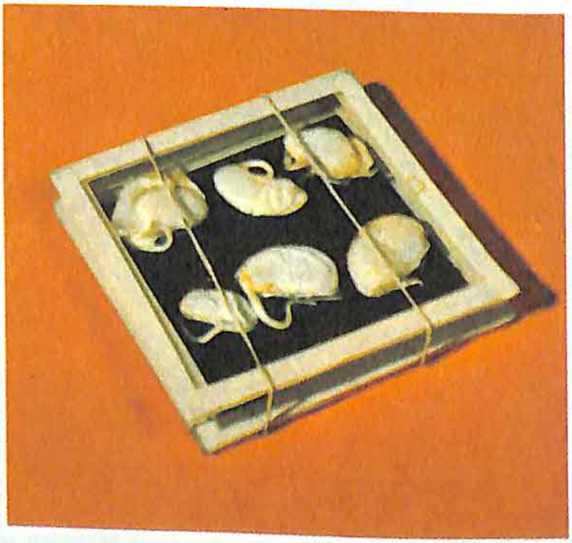
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BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Generally, when substances are heated, they
   a. expand b. contract
2. The surface of a rock when heated and cooled may
   a. peel off b. be built up
3. Roots of a plant may cause a rock to
   a. disappear b. break apart

USING WHAT YOU KNOW

1. How does expanding and contracting help break down a rock?

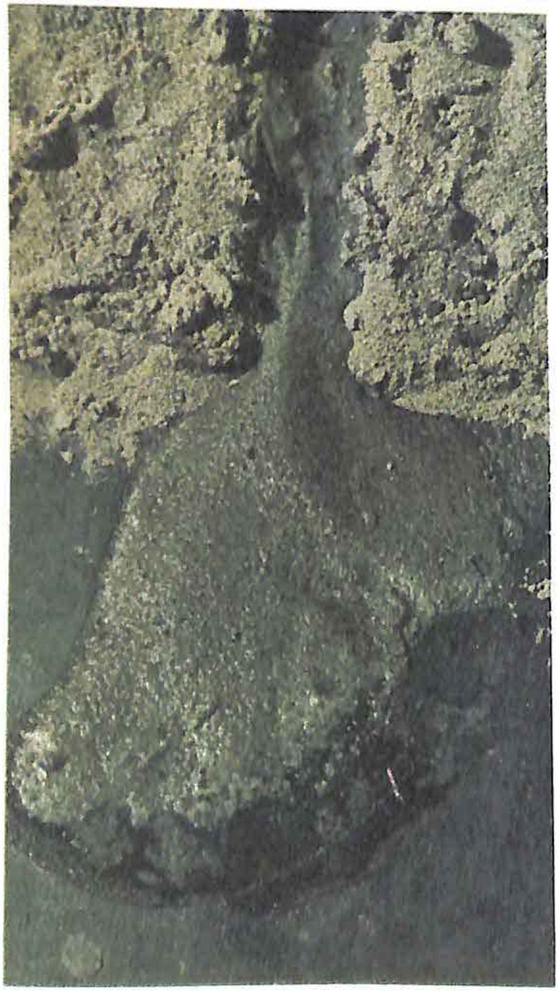
2. When rock is heated, it expands. When air is heated, it expands. Do you know a substance that expands when it is cooled?

3. There are air spaces between lengths of steel rails. What would happen if there were no spaces between these lengths of rail? Why?

ON YOUR OWN Collect some evidence with a camera to show what plants can do to rock. Write on the back of each picture where and when you took it, and what you think the plant is doing to the rock.

4. Building Up the Land

We have seen how ice and heat and plants break up rock and how running water carries away soil and small rocks. We have seen how the land is being torn down and moved away. Little by little, the mountains are being worn down, and the soil is being carried away by running water.



What happens to this soil and rock? We can find out if we look once more at our model river, in the investigation on page 221. The model river, you remember, carried sand down to the bottom of the sand hill. In fact, the little river made a small pile of the sand that it had carried along at the bottom of the hill. ■ The water made a model lake there, where it dropped the sand.

Why did the model river drop the sand it was carrying at the bottom of the hill? Try the investigation on the opposite page. It will help you to answer this question and perhaps others.

Down in the Valley

The model river dropped its load of sand where it did for a reason.

AN INVESTIGATION into Moving Water

Needed: a large jar, some coarse sand with small pebbles in it, a spoon, water

Put about an inch of sand in the jar. Then add water until the jar is about three-fourths full. ■

When the sand has settled to the bottom of the jar, begin to stir the water gently around the jar with the spoon. Do not let the spoon touch the sand. Keep the spoon near the surface of the water. ● Observe how much sand the water is carrying along.

Now stir the water faster. Does the load it can carry change? Stir still faster. What happens to the amount of material carried as the water moves faster?

Take the spoon out of the water quickly. The whirling water begins to slow down. As the water slows down, what happens to the load it is carrying?

Here is what happened in one trial. ▲ ◆

Additional Investigation: As the water slows down, do the heavier particles or the lighter ones drop out first?

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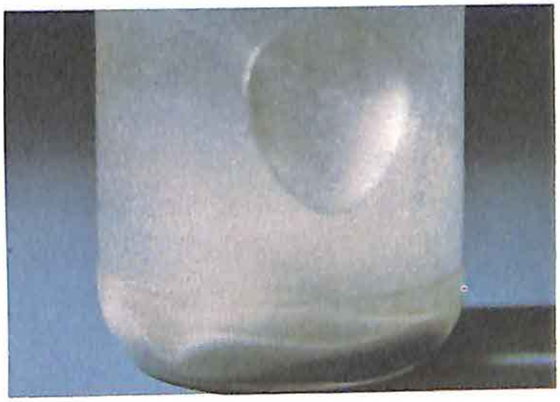
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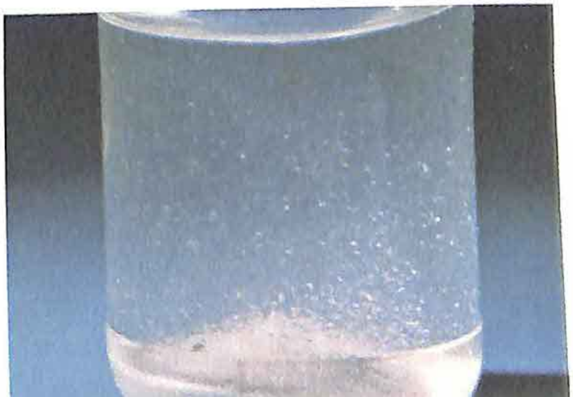
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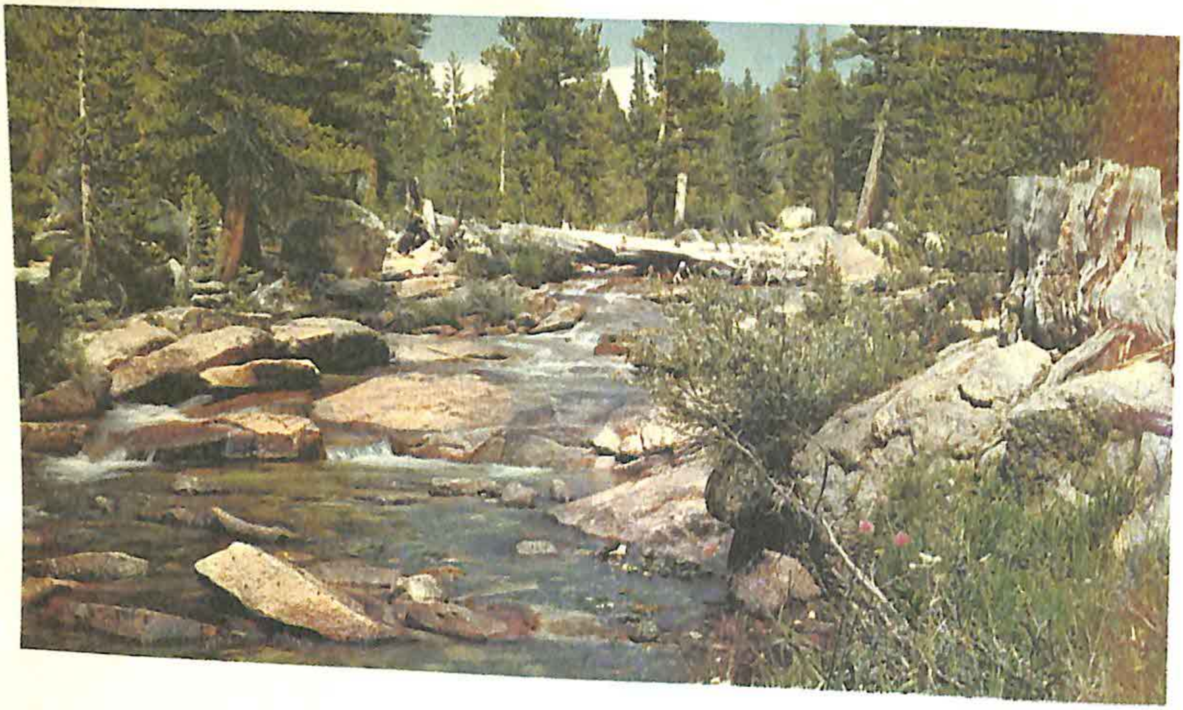

The running water slowed down there. When the running water slowed down, it could not carry as much sand as it had been carrying. So the water dropped most of its load of sand at the foot of the little hill, where the water slowed down. The faster water flows, the more material it can move along. The slower it flows, the less it can carry.

Why did the model river slow down just at that place? It was because the water was not running downhill any longer, of course.

When the water in the model river suddenly slowed down, it dropped a lot of the sand it was carrying along. Does the same thing happen in a real river? See for yourself. Here is a photograph of a place where a stream enters a valley. The fast-running water suddenly slows down. As you see, it drops soil and rocks that it was carrying. ■

The bits of soil, rocks, leaves, and other materials that a river carries and drops are called **sediment.** Some of the soil and rocks taken from the mountains is carried into valleys and dropped as sediment. The running water may drop layer upon layer of sediment. Thus *land is built up in the valleys,* even as it is torn down in the mountains.

If you live near mountains or if you have visited them in the winter, you know that they may be covered with a deep blanket of snow. Ice is also at work breaking up the rocks. Spring comes and with it warm rains that melt the snow and ice. Many streams rush down the mountainsides carrying large amounts of soil and bits of rock. The streams join to make a river that flows through a valley.

A river flowing through a valley becomes swollen with rain. It is carrying much sediment and moving swiftly. ● The river rises and overflows its banks, flooding the valley. ▲ Where the valley is flooded, the water now moves *slowly*. The water drops much of its load of sediment. When the flood waters go, that sediment remains in the valley. ◆ Thus the land in the valley is built up.

Down to the Sea

Imagine rain falling on hills and mountains and running into small streams. The small streams run into larger streams, the larger streams tumble into rivers. Small rivers join to make big rivers, such as the Ohio, the Mississippi, the Columbia, and the Delaware. After a time, some of the sediment may come to rest at the bottom of the sea.

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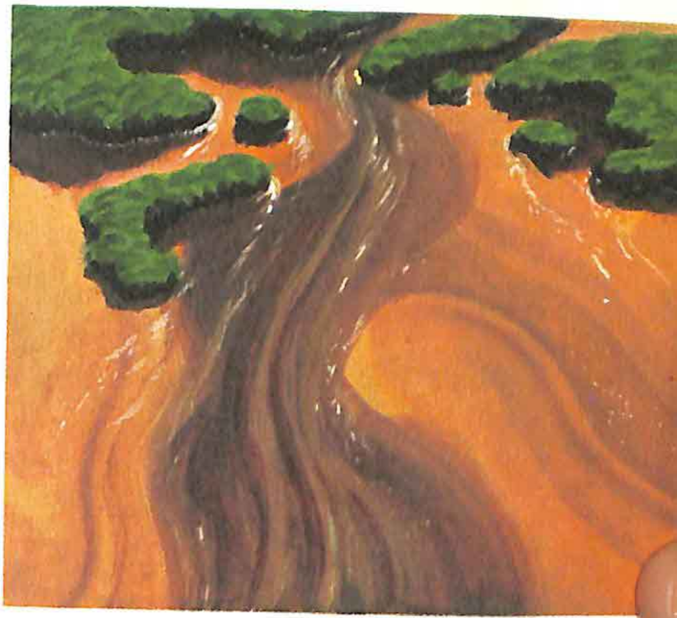
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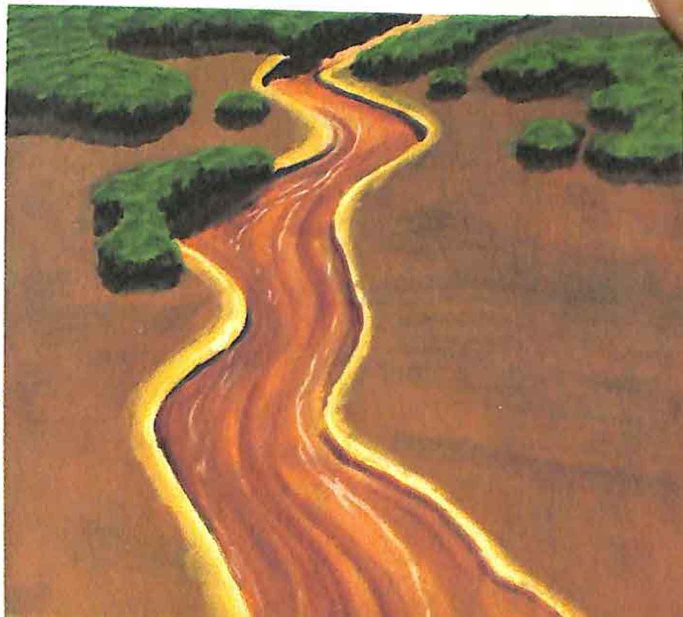
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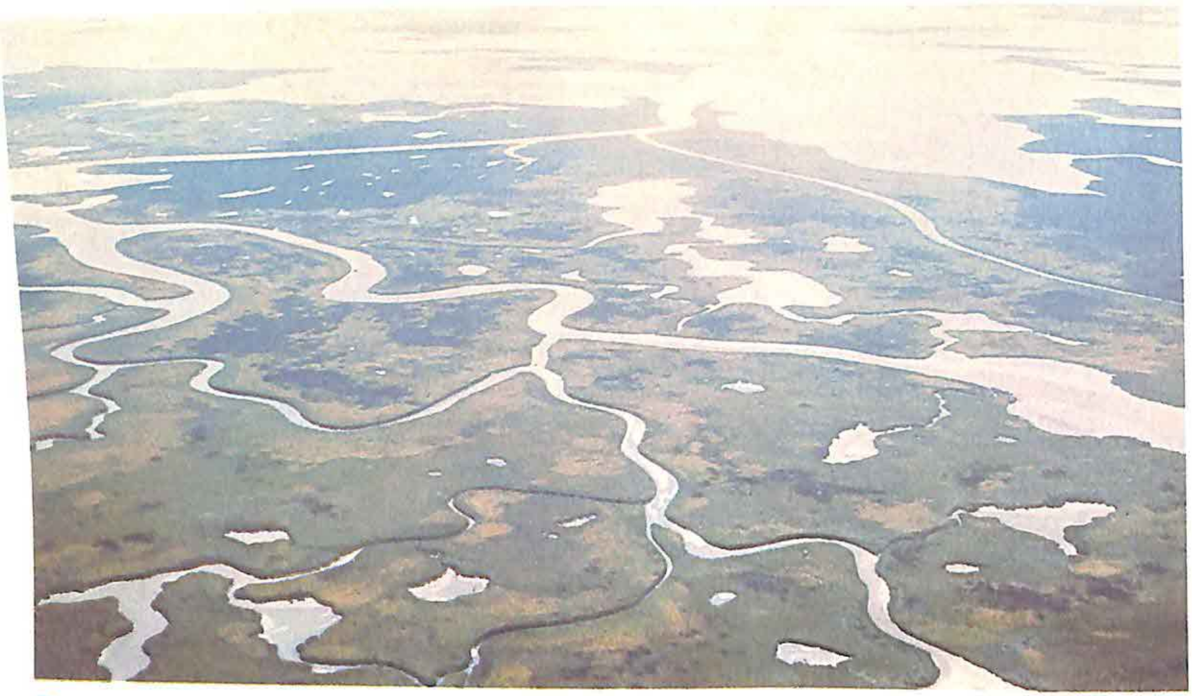

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The place where a river pours its water into the sea is called the **mouth** of the river. At the mouth of a river, the water usually slows down as it meets the sea. As the river water slows down, it drops some of the sediment it is carrying, of course. As a river drops sediment at its mouth, it builds up land there. Here is the mouth of the Mississippi River. ■ Can you see where the river has dropped sediment? Each year the Mississippi River becomes a little longer, as more land is built up at its mouth.

You might think now that when the Mississippi has reached its mouth, it has dropped all its soil and rock. But it hasn't. The river still has sediment in its water. This sediment is carried out to sea and dropped on the sea bottom. The land at the bottom of the sea is being built up by every river that carries soil and rock down to the sea.

The land is being torn down and carried away in some places. In other places the land is being built up, built up with the soil and rock that was torn down.

A handful of soil now on a hill in Ohio may travel to the bottom of the sea in a year or two. Another handful of soil on a mountain in Oregon may travel to the Pacific Ocean in the same time.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Whenever land is being broken down, land is being built up
   a. in the same place b. in another place

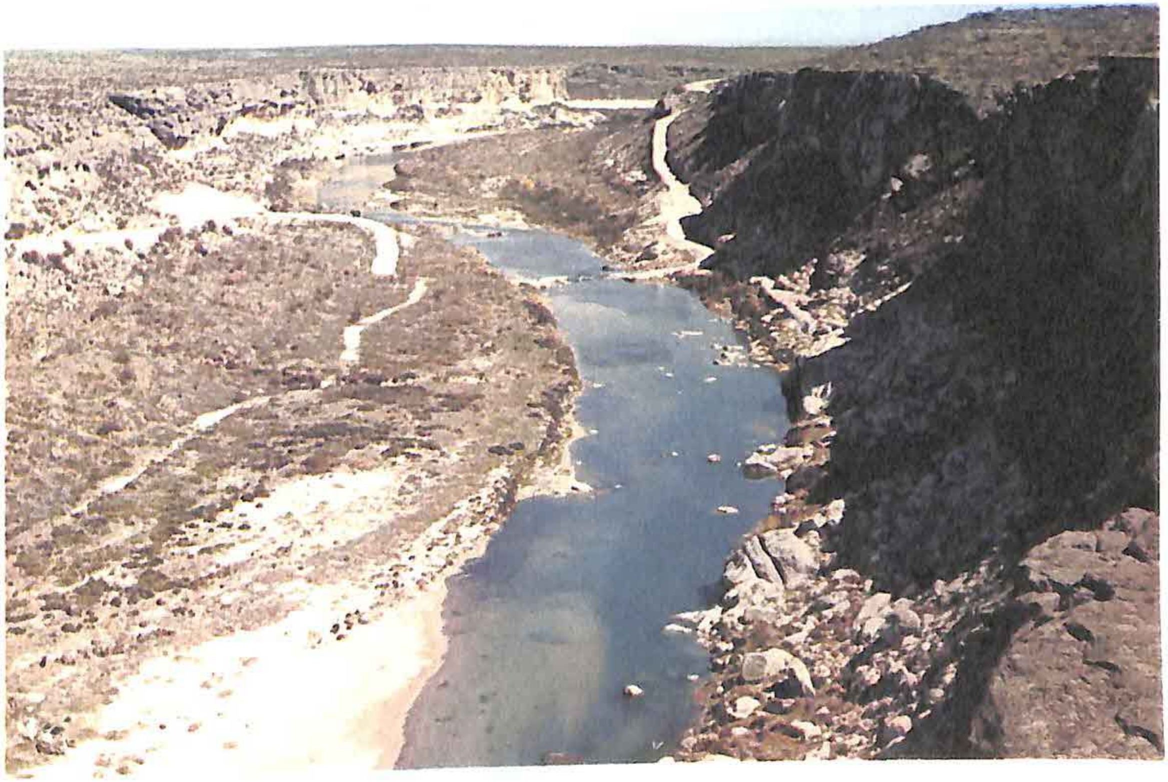
2. Land is built up at the mouth of a river as soil is
   a. dropped b. carried away

3. Bits of rock and soil from a mountain
   a. may be found at the bottom of the sea
   b. can never be found in the sea

STATE INSTITUTE OF EDUCATION

USING WHAT YOU KNOW

1. Is there any evidence in this picture to show that more water once flowed in this stream?



2. The Nile River in Egypt floods its valley every year. After the flood waters leave, farmers begin their planting. Why is the soil in the valley richer after a flood?

3. Do you agree or disagree? Tell why.
   a. As land is worn down in one place, it is built up in another place.
   b. The slower a stream flows, the more soil and rock it can carry along.

ON YOUR OWN Look for evidence after a heavy rain to show that when running water slows down, it drops part of what it is carrying. Photograph the evidence or make a drawing of it to show to your class.

5. Holding Land and Water

Water can carry soil away.

We need soil. We must have soil to live. Are there ways to keep water from carrying soil away? Are there ways to hold soil?

Here is a geranium plant that is growing well. Hold the plant and tap the pot on the side to loosen the soil. ■ Lift the plant out of the pot. ● The soil comes out as well. What is holding the soil together?

Pull up a few weeds and look at their roots. What comes up with the roots? Try to take all the soil off the roots. It is not easy. The weed roots hold soil.

Roots hold soil. Where there are no plants and the soil is bare, water can carry the soil away. But if plants are growing in the soil, their roots hold on to the soil. Water cannot wash the soil away easily. This is one reason why it is important to have forests. Trees have many roots, and their roots hold much soil.

Trees help to hold soil in another way. The leaves of a tree can act as a **cover.** A cover is a kind of shelter that protects soil from being washed away.

Cover in a Forest

If you have ever been under a tree when it started to rain, you

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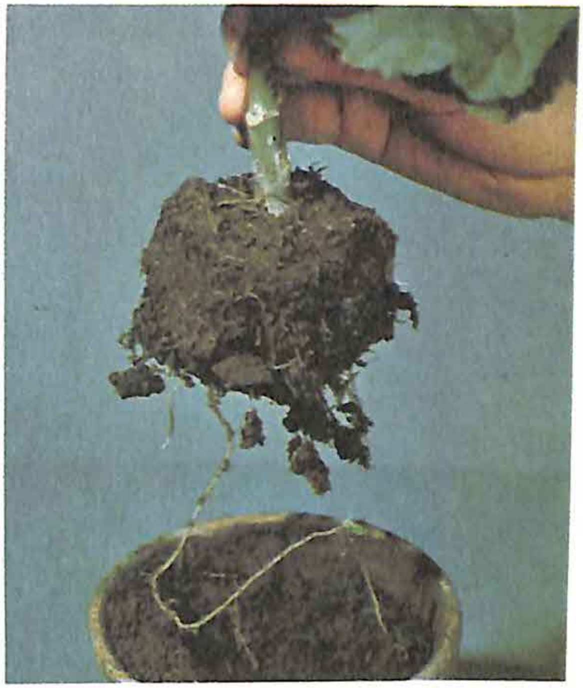

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have probably heard the sound of raindrops hitting the leaves. It is an important sound. It means that the leaves are helping to hold the soil. Raindrops that hit leaves first do not hit the soil hard. They drip down onto the soil. When there are no leaves, the raindrops can hammer at the soil, break it up, and wash some of it away. Leaves on the trees act as cover. In the fall, when leaves drop to the ground, they again act as cover. The carpet of leaves keeps the soil from being washed away.

Have you ever been in a pine forest? The trees are so close together that you are sheltered from a gentle rain for a while. Then the rain begins to drip gently to the carpet of pine needles under your feet. This deep cover several inches thick soaks up the heaviest rains. An oak or maple forest usually has shrubs, ferns, and other small plants growing among the trees. These, too, break the force of rains and their dead leaves add to the cover of the forest floor.

Both leaves and plants help to hold soil. There is one plant, however, that is especially important for holding soil in place. This important plant is grass. But first see how a cover protects the soil. Try the investigation on the next page.

AN INVESTIGATION into How Leaves Help to Hold Soil

Needed: some soil or sand, four or five leaf-sized pieces of paper, a sprinkling can, a brick or wood block, an empty aquarium or large pan

Make a flat pile of sand on the brick or block in the aquarium or pan. Lay paper "leaves" on the sand. ■

Sprinkle the sand with water. The higher the can is above the sand, the harder the "rain" will fall. ●

What happens to the sand under the cover of the "leaves"? What happens to the sand that was not under cover?

Here is what happened in one trial. ▲

Additional Investigation: Place some pennies on a flat pile of sand. Predict what will happen if you sprinkle the sand with water. Test your prediction.

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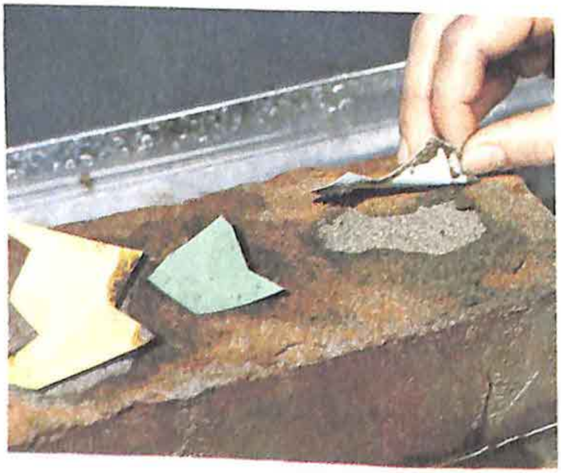
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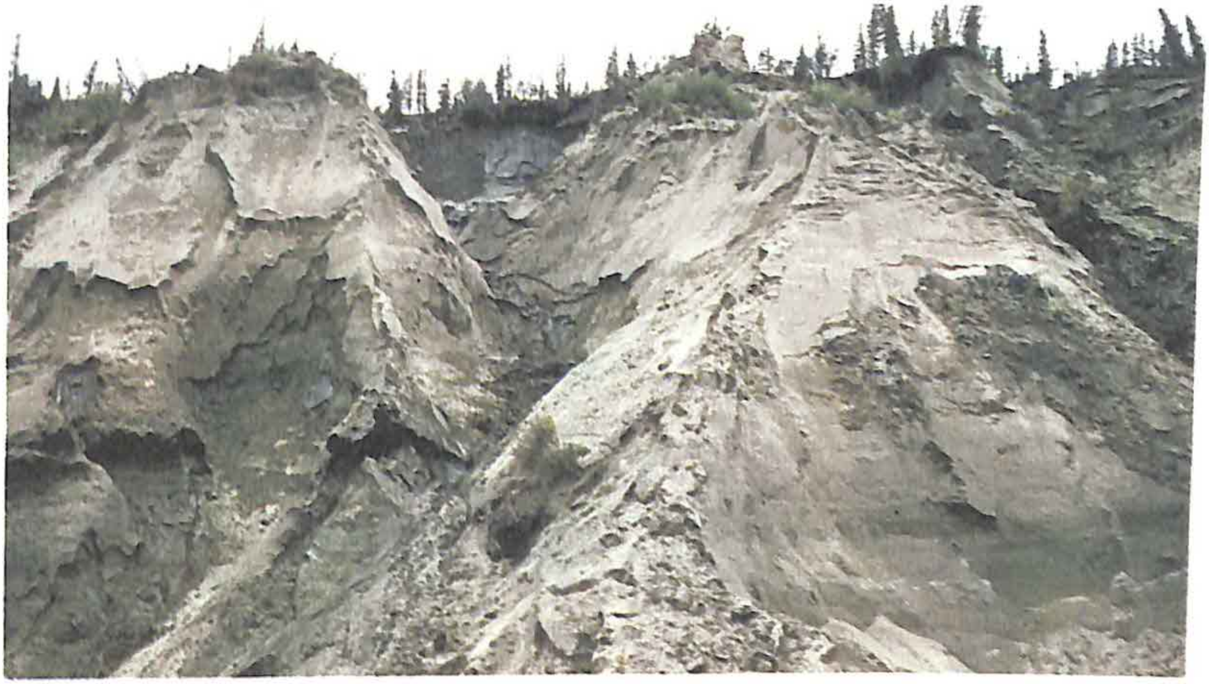


■

Saving Our Soil

Soil on a bare hillside is easily washed away by rain. In time, the running water cuts deep into the soil. It makes deep slits and ditches called gullies. When there is a heavy rain, streams of water flow down the gullies and make them deeper and wider. In time, so much soil may be washed away that the hillside may look like this. ■

But if a bare hillside is planted with grass, the story will be different. Grass is a cover for soil. The roots of the grass hold soil and keep it from being washed away. Gullies do not get a chance to start. Something else happens as well where grass grows. The rain soaks into the soil. Water that soaks into the soil does not run off to do damage elsewhere. The grass roots hold the soil, and the soil holds the water.

If a gully has become deep, planting grass may not be enough. Dams may have to be built across the gully to break the force of running water and to catch the soil it may be carrying. Vines, shrubs, and seedling trees can be planted along the sides. In a few years, the cover they provide will slow down the flow of water. The soil can be built up again so that it will be useful.

There are many ways of holding the soil we need.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. To hold soil, we should
   a. cut down trees b. plant trees
2. To hold soil, we should
   a. permit leaves to remain on the forest floor
   b. remove leaves from the forest floor
3. To hold soil, we should
   a. permit plant roots to remain in the ground
   b. dig up the plant roots

USING WHAT YOU KNOW

1. Do you agree with these statements? Tell why.
   a. We need soil.
   b. Roots break up soil, causing it to be washed away.
   c. Leaves make a good cover.

2. The kudzu vine has large leaves and grows very quickly. Can you think of a good use for such a plant?

3. A farmer has a field on the side of a hill, which he is going to plow. If he wants to keep his soil from being washed away, should he plow up and down the hillside? across the hillside? What is your reason?

ON YOUR OWN Photograph some examples of soil being washed away. Decide what you think might be done to stop it, in each case.

6. The Rising Mountains

From a distance, mountains seem unchanging and able to last forever. When we look closer, however, we see cracks in the rock, pieces of rock that have broken off, and streams carrying soil and rock away. We know that the mountains are always changing. Water, ice, the heat of the Sun, plants, and other things are wearing down the mountains.

As water runs down hills and mountains, it picks up soil and rock and carries them along. It drops them in the valleys and plains, at the mouths of rivers, and on the sea bottom. Thus, in one place land is being worn down. In another place land is being built up. ■

All along our shores there are rivers running into the sea. All along our shores these rivers are carrying soil down to the sea. Millions and millions of tons of sediment are laid on the sea bottom every year by rivers. A tremendous weight of soil and rock is built up on the sea bottom along the shore. This weight of sediment along the shores gets so great, we think, that it makes a change in the Earth. To understand what this change is, and how it happens, you should first know something about the inside of the Earth.

Do you think that the Earth is solid rock all the way through?

■

Inside the Earth

Scientists have found that our Earth is not cold, hard rock all the way through. Not at all. Only the **crust** of the Earth, the outside, is solid.

Below this solid crust of the Earth there is hot, melted rock. Every now and then some of this hot rock is pushed out through the solid crust, rather like toothpaste being squeezed out of a tube. When this happens, a **volcano** is made. ■

The melted rock below the Earth's crust can flow, like toothpaste, if it is squeezed. If you squeeze a partly filled tube of toothpaste in one place, what happens? The toothpaste flows to another part of the tube. If you press down on one part of the tube with a finger, what happens? The tube rises in another place as the toothpaste flows there. ●

Strangely enough, the Earth may be behaving like a tube of toothpaste. If the Earth is pressed down in one place, it may rise in another place. And hot melted rock within the Earth may flow to another place as the Earth is pressed down.

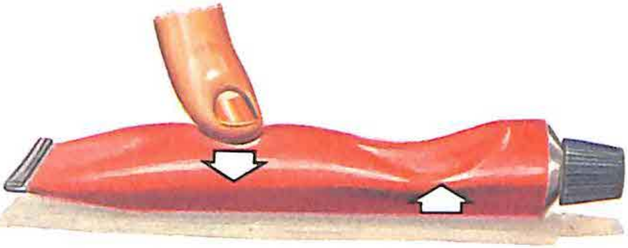
What could press down on the Earth's crust in one place?

Up Go Mountains

Along the seashore, rivers are dumping sediment into the sea. (Sediment includes all the bits and pieces of soil, rocks, leaves, and other materials that a river picks up.) This is going on now. It has been going on for millions of years. On the bottom of the sea, near the shore, the load of sediment gets heavier and heavier. The growing weight of sediment presses down on the Earth's crust harder and harder. The growing weight of sediment presses on the melted rock inside the Earth, harder and harder.

Think of this, too. As the weight of sediment on the sea bottom is getting heavier, the mountains are getting lighter. The mountains are being worn down, remember.

The sediment brought from the mountains presses down in one place. The Earth's crust may rise in another place. It may rise under the worn-down mountains. It may rise along the seashore, near where the sediment is pushing down. Where the crust rises, it may make mountains. ▲



●

It may be, too, that heat inside the Earth helps raise mountains. As sediment falls on the sea bottom, it makes a kind of blanket. The part of the Earth under that blanket becomes warmer. The heat may cause the rock to expand and to push up the crust.

This is one explanation of how the crust of the Earth is pushed up. There are other explanations which you will study as you go on in science.

We do know that there are places where the Earth's crust is rising. We do know that there are mountains that are rising, ever so slowly. Some scientists believe that this rising is

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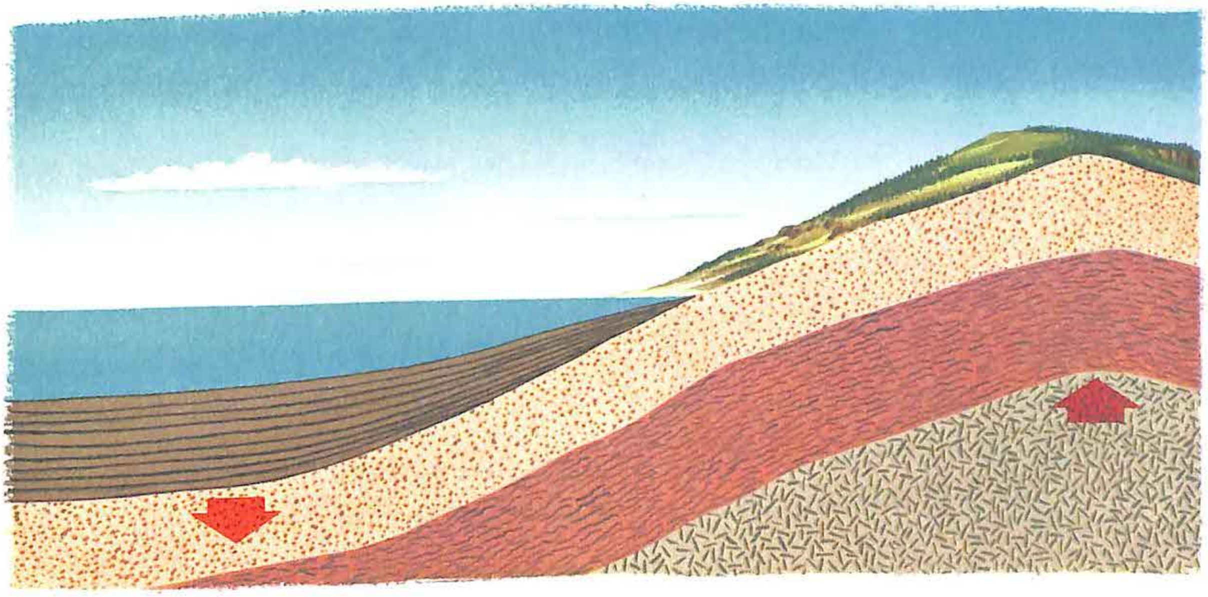

explained by the weight of the soil and rock dumped into the sea by rivers. Others believe that the heat trapped under the blanket of soil helps raise these mountains, even though very slowly. If you look at a map of the United States, you can notice something interesting about our mountain ranges. They run in the same direction as our coasts. This is what they might be expected to do, if they were somehow connected with the seashore.

Land is worn down. Land is built up. Mountains rise again. The Earth is never still. It changes all the time. It changes every second, every year, as it has been changing for many millions of years. It will keep on changing.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. The inside of the Earth is
   a. hot b. cold
2. Heat inside the Earth may
   a. press mountains down b. help raise mountains
3. The pressure of great weights of sediment may
   a. help raise mountains b. press mountains down

USING WHAT YOU KNOW

1. How can heat under the crust of the Earth help to lift mountains?

2. As old mountains are being worn down, new mountains are rising up. Do you think this is a cycle? Why?

ON YOUR OWN

Clams live in the sea. Yet clam shells millions of years old are found in rock on top of a mountain. How do you explain this?

7. The Main Concept: The Earth Is Changing

The Earth is changing, changing all the time. Often we do not notice it, because many of the changes happen so slowly. Yet they are happening. Rocks are breaking down. Water seeps into cracks at the top of mountains. The weather gets cold and the water changes to ice. As it does so, it pushes against the sides of the cracks. The rock splits and breaks up. In summer, roots of plants work into other tiny cracks in the rocks and widen them still more. Then, in winter, ice works again to widen the cracks. Melting snows and spring rains move rocks and soil (and bits of dead plants and animals) down the mountain into the valley.

These bits of rock and parts of plants and animals make more soil. More plants can grow in this soil. As they die, they add substances to the soil. So more soil is always being made.

As plants and animals grow and die, the soil is being changed, too. The dead animals and plants are putting useful substances back into the soil. They are making the soil good for more plants to grow in, providing food for animals.

Running water is picking up soil in one place and dropping it in another place. Plains and valleys are being built up with soil in which plants can grow. Plants are useful in saving soil, too. If water runs too fast, the good soil is carried away and only poor soil is left. Plants do not grow well in poor soil. If there are enough plants—trees, bushes, and grasses—water does not run off so fast. Plants keep water from carrying off soil. This means that the substances plants need remain in the soil.

Streams carrying soil are flowing into rivers. Rivers are emptying into seas and dropping rock and soil and other materials along the seacoast. The weight of this sediment on the sea bottom is getting heavier and pressing down harder. Under the sediment at the bottom of the sea, under the Earth's crust, melted rock is moving and pushing against the crust. As the Earth's crust is pressed down in one place, it is pushed up in another—and mountains are slowly rising.

Yet even as they are rising, the mountains are being worn down, and land is being built up somewhere else. It happens over and over again. It is happening now. The surface of the Earth is always changing and will always keep on changing.

Fixing the Main Concepts

TESTING YOURSELF Study the statements below and choose the correct responses. They will help fix in mind the main concepts.

1. Small pieces of rock are found broken off a big rock. They may have been broken off by
   a. heat b. wind
2. Rivers that move slowly are not likely to carry
   a. large stones b. small particles
3. When muddy water slows down, soil is
   a. dropped b. picked up
4. Grass is important because it can
   a. break up soil b. hold soil
5. In a forest, the soil is protected against hard rain by
   a. leaves on the ground b. open spaces
6. The heat of the Sun acts mainly to
   a. build up mountains
   b. break down mountains
7. The heat below the surface of the Earth acts mainly to
   a. raise mountains
   b. break down mountains
8. Heat and water can break down the rock of a mountain; so can
   a. animals b. plants
9. A river may get longer by dropping sediment
   a. anywhere b. at its mouth
10. The surface of the Earth is
    a. not changing b. changing

FOR YOUR READING

If you want to learn more about our changing Earth, these books will be useful.

1. *Rocks, Rivers, and the Changing Earth*, by Herman and Nina Schneider, published by William R. Scott, 1952. Here is a very good introduction to geology, the science which is the study of the Earth.

2. *The Story of Rivers*, by Ray Bethers, published by the Sterling Publishing Company, New York, 1957. This book tells the story of today's rivers and shows the importance of these rivers to man.

3. *You and the Earth Beneath Us*, by Julian May, published by the Childrens Press, Chicago, 1958. In this book you will find interesting information about mountains, volcanoes, glaciers, soils, and many other features of the Earth.

GOING FURTHER

An Investigation

Different kinds of soil have different kinds of fungi living in them. To study these different fungi, collect some soil samples. You can keep the different soils in clean pint jars. Be sure the jars are dry. Fill each jar to the brim with soil. Cover the jars with wax paper fastened with a rubber band. Some of the kinds of soil that you might collect are: garden soil; sandy soil; clay soil; soil from a forest; soil from the side of a pond; soil from about 1 foot beneath the surface, if possible; soil that is usually moist; soil that is usually dry. Do not forget to label each jar.

Place two tablespoonfuls of a sample of soil in a plastic bag. Add one-fourth of a slice of bread. Close the bag and label it. The molds will begin to grow. Do this for each of your samples.

Which soil produces the richest fungus life? You can observe the speed with which molds grow and the number of different kinds of mold. CAUTION: *Once molds begin to grow, do not open the bags.* Remember that molds reproduce by spores. The spores can spread from an opened bag and spoil food.

Keep a record of your observations. Drawings and photographs will help. In a few weeks you may have an idea of which soil is richest in fungus life. (How do your results compare with someone else's?)

How will you know that the molds did not come from the bread? Can you plan your investigation to make fairly certain that the molds came from the soil?

Beginning a Hobby

To learn about soil, use it, dig it, care for it. A farmer's life depends on keeping his soil in good condition. Your life does too, for you depend on the farmer.

One way to learn about soil is to start a garden, even if the garden is only a few flowerpots or window boxes. Perhaps you know someone who can help you begin. You may want to start with a book, perhaps this one.

First Book of Gardening, by Virginia Kirkus, published by Franklin Watts, New York, 1956. This book is for beginners, and it should give you a good start.

You don't need much land to begin a garden. All you need is a sunny spot, perhaps 6 feet long by 6 feet wide. The soil should be at least 12 inches deep. Of course the soil should have humus in it and not be too sandy. Suppose you decide to grow beans and tomatoes. You can grow 6 tomato plants and 2 or 3 rows of bean plants. When they are ready to pick, your tomatoes and beans will be fresh, and they will taste fresh—not like canned or frozen food. Instead of beans and tomatoes, you may prefer to grow peas and radishes.

You can grow flowers in a small garden: daffodils, zinnias, snapdragons, asters, and many other colorful and beautiful kinds. Catalogs from seed and plant breeders can help you make a choice.

Why is growing plants fun? Why do people like this hobby? For one thing, they like being outdoors as they turn over the soil and weed the garden so that the plants can grow well. For another, they like watching how what they do helps the vegetables grow better, or the flowering plants grow larger with more blossoms. They like seeing how fertilizers and watering and regular weeding help the plants grow.

Gardening is a hobby that can grow from year to year. But you can start with a few flowers or vegetables, depending on how much land you have and how much time you want to spend. In time, you may become an expert.

Unit Eight

THE VOYAGE OF HALLEY'S COMET

(Text pages 254–79)

UNIT CONCEPT
The motion and path of celestial bodies are predictable.

A Preview of the Concepts

Children begin to understand motions of celestial bodies such as the Moon, comets, and meteors, how scientists have developed concepts of these motions, and how they are able to predict such motions.

A VIEW OF THE UNIT

Children have observed that the Moon seems to change shape and that the changes are repeated at regular intervals. And they, unlike most of us, ask what does this changing shape mean? It happens that the change means something very important. Children make the discovery, using a flashlight and a ball, that this apparent change in the shape of the Moon is evidence that the Moon is moving, moving in space around our Earth. The Moon is in continual and regular motion around the Earth, scientists have found, in a definite orbit, with the same side of the Moon always turned to the Earth.

Comets, however, seem to have no regularity at all. A comet appears without warning in the sky. It looks like no other celestial body. It moves across the sky for an uncertain length of time. Then it disappears. Is it any wonder that comets were feared in ancient times, looked upon by people as signs of disasters to come? But a scientist named Halley, with the help of another scientist named Newton, showed that there is regularity among comets. Calculating the orbits of comets, Halley made the astonishing discovery that one particular comet had appeared in the sky about every 76 years, following an orbit that took it out beyond the planet Neptune and then back around the Sun again. His prediction that this comet would reappear came true; thus comets were found to be part of the regular order of celestial events. By making a scale model of the solar system on the floor, children can discover the extent and shape of the orbit of Halley's comet.

Newton helped Halley by telling him that the orbit of a comet that approaches the Earth from time to time must have a certain shape, a shape called an ellipse. Newton knew this because he had figured out that the pull of gravitation was what shaped the orbit of a comet. The pull of gravitation, said Newton boldly, is not just something that makes apples (and other objects) fall; it is not just something that pulls objects on the Earth; the pull of gravitation reaches out from the Earth to the Moon. The pull of gravitation exists between the Sun and the planets. Indeed, there must be gravitation between every two objects in the universe. If the pull of gravitation extends from the Earth to the Moon, why doesn't the Moon fall to Earth, then? Children find that an investigation with a ball and a length of thread supplies evidence that ties in with something learned earlier, that the Moon is moving.

What is a comet made of? Scientists are not altogether sure, but a comet's head is probably a mixture of ice and bits of rock—a huge dirty snowball. Its tail is a stream of very thin gases, so thin that the pressure of light from the Sun can swing the tail away from the Sun. Meteors, often called "shooting stars," may be bits of rock from a comet's head that has disintegrated. As a lump of rock speeding through space encounters Earth's atmosphere, friction makes the rock hot enough to give off light. A meteor that hits the ground is a meteorite.

Scientists can predict the motion of the Moon, the planets, and some comets. They can even predict when showers of meteors will appear. But these predictions are not based just on the fact that an event has always happened in the past and so can be expected to go on happening in the future. Scientists have some understanding of what shapes the orbit of a planet or a comet or the Moon, and what keeps planet or comet or Moon moving along that orbit. So long as these principles continue to operate, predictions can be made.

The celestial bodies are always in motion. Even the stars, which seem fixed to our eyes, are moving. There is continuous change in the skies. Yet in this change scientists have found regularity and order.

SUPPLEMENTARY AIDS

All films and filmstrips are in color and considered to be of approximately the same level of conceptual understanding as the textbook. Full names and addresses of distributors and suppliers are on page F-25.

Films

The Moon (12 min., sound), Cenco, 1963. Shows the physical characteristics of the Moon's surface; the orbit of the Moon around the Earth; the phases of the Moon; and the effect of the Moon's gravitational pull on the oceans, causing high and low tides.

Outer Space (13 min., sound), Cenco, 1963. Describes the different kinds of stars, their color and grouping in constellations and galaxies; shows star charts of constellations that are visible at all times; explains that comets are visitors from outer space; describes appearance of comets.

Asteroids, Comets and Meteorites (11 min.), F.A. Shows how astronomers have learned about these objects that are traveling around the Sun; what each group looks like; and the place of each in the solar system.

Gravity, Weight and Weightlessness (11 min.), F.A. Describes weight as the measure of the pull of gravity; demonstrates Newton's experiment concerning freefall; shows how scientists use their knowledge to launch objects into orbit.

Stars (12 min.), I.F.B. Explains the relative fixed positions and circular movements of stars in the sky; identifies common constellations; shows our Sun and solar system.

Filmstrips

Constellations We Can See (45 frames), McGraw-Hill, 1962. Explains comets and meteorites; shows how to recognize some of the best known constellations; Big Dipper, Little Dipper, Draco the Dragon, Dog Star, and Leo.

Gravity (49 frames), McGraw-Hill, 1953. Drawings explain that gravity is the pull exerted by the Earth on everything on it and around it; the heavier the object, the greater the pull of gravity; the farther from the center of Earth, the less the force of gravity.

Moon Our Nearest Neighbor (42 frames), McGraw-Hill, 1952. Drawings explain the Moon's orbit around the Earth; the phases of the Moon; what causes the tide changes; an imaginary trip to the Moon.

The Sun and Its Family (46 frames), S.V.E., 1956. Explains the differences of planets, asteroids, comets, and other elements of the solar system; also shows the action and meaning of gravity, solar energy, and the seasons.

Our Earth in Motion (39 frames), Jam Handy. Explains rotation of the Earth; the Earth also travels in a path around the Sun; gravity keeps the Earth in the same path.

Science Reading Table

Starred (*) titles are recommended as especially suitable for the level of reading and conceptual development. Other titles have sections especially useful for reference and development of individual concepts. Names and addresses of the publishers are on page F-24.

A Book of Planets for You, by Franklyn M. Branley, Crowell, 1951. The sizes, temperatures, and satellites of the planets are described. Simple investigations show how the planets revolve and rotate, where they are located in relation to Earth and in relation to one another. "Are there canals on Mars?" "What are the rings of Saturn made of?" and similar questions are answered. (Easy)

**The Earth in Space*, by John and Cathleen Polgreen, Random House, 1963. The reader takes an imaginary trip far out in space. Concepts about the immensity of space are suggested over and over as the journey continues. Information about planets, galaxies, and stars is included. (Average)

Man on the Moon: Our Future in Space, by James Throneburg, Knopf, 1961. Describes an imaginative trip to the Moon based on scientific fact. Questions such as "Where did the Moon come from?" "Why were people once afraid to walk in the moonlight?" and "Is there water in the 'seas' of the Moon?" are answered. (Advanced)

**The Moon Seems to Change*, by Franklyn M. Branley, Crowell, 1960. Describes the relationships between the Earth, Sun, and Moon that result in phases of the Moon. Brilliant color and unusual black-and-white illustrations both inform and delight the reader. (Easy)

Satellites in Outer Space, by Isaac Asimov, Random House, 1960. Explains how scientists use satellites to find out more about the Earth, the Moon, and outer space. Many satellites and space problems are described. (Advanced)

The Sun, the Moon, and the Stars, by Mae and Ira Freeman, Random House, 1959. Contains a few easy investigations to help in concept development about rotation of the Earth, the pattern in which sunlight falls on the Earth, the apparent change of the shape of the Moon, stars of the Milky Way, and other basic facts about the Sun, Moon, and stars. (Easy)

What Makes Day and Night, by Franklyn M. Branley, Crowell, 1961. Very simplified description about the mechanics of the Earth's rotation and the apparent changes in the position of the Sun that result from the rotation. Brilliant color illustrations accompany the narration. (Easy)

°*What Is a Star,* by Daniel Q. Posin, Benefic Press, 1961. A miniature encyclopedia of the topics useful for beginning study of the stars. Contains brief statements on formation of stars, how distances and sizes of stars are measured, the light spectrum, the constellations; and touches upon the use of telescopes. (Average)

°*You Will Go to the Moon,* by Mae and Ira Freeman, Random House, 1959. "Here is the rocket that will take you up into space." The rest of the story describes the trip. The science of the Moon trip is summarized in a separate section at the end of the book. (Easy)

▶ INTRODUCING THE UNIT

In the year 1910 Halley's comet appeared in the sky and was visible to the unaided eye for several weeks before it disappeared again. Let the children examine the opening illustration on text page 254 to begin with. If you had been there, among the people watching the great comet, what would you have felt? What questions would you ask? What do you think the comet is made of? Where did it come from, and where is it going? How old would you be now?

Does any child in your class know a person who remembers seeing Halley's comet in 1910? Perhaps a parent remembers hearing his parents or grandparents tell about it. An interesting tale might be revealed for the class if children inquire. How did persons feel about the comet then? Were they excited, or did they pay little attention?

Invite the children to answer the questions on text page 255. The immediate response may be that scientists have figured out these answers, that the comet will appear again, at a certain time. But how have scientists figured them out? Do we just take the scientists' word, because they are scientists? Should we always accept what an expert says, or should we sometimes question it?

As it happens, we can understand how scientists can figure out an event such as the possible return of a comet. That's what this unit is about. The Moon is a good place to begin our understanding. You can see something happening to the Moon that is an important clue. You have seen it happen often, and you will see it happen often in the future. What can it be? It is the *changing shape* of the Moon.

Section 1: THE VOYAGE OF THE MOON

(Text pages 256–60)

SUBCONCEPT

The changing shape of the Moon is due to its motion around the Earth.

Processes emphasized

Observation
Analysis of observations
Hypothesizing
Theorizing
Prediction
Investigation (with building and analysis of models)
Library research
Measurement

Children learn that the shape of the Moon changes because the Moon is moving around the Earth.

Introducing the Concept

"The answer begins with a look at the Moon," reads the last line of the unit introduction on text page 255. Before turning the page to begin this first section, it is useful to explore what the children know (or think they know) about the Moon. You might ask for sayings about the Moon, as well as whatever facts the children have. (If you call for superstitions, instead of sayings, you probably won't get as many.) For instance, there is the notion that to look at the new moon over one's left shoulder is bad luck. Potatoes should be planted when the Moon is dark; peas should be planted in the light of the Moon. There may be some sayings about the Moon that are peculiar to your locality, for such sayings vary from place to place.

You may have children whose imaginations have already been fired by the prospect of men traveling to the Moon; they need no goad to stimulate interest. They have often seen its changing shape, but have they understood what important information about the Moon's travels this changing shape reveals?

Why does the Moon seem to change shape?

Invite hypotheses; then ask for evidence. Some is suggested by the text; read as far as **The Light of the Moon,** and do the investigation. The photographs of the Moon on page 256 were taken 3, 5, 8, 11, 14, 17, 20, 23, and 26 days after the new moon.

Developing the Concept

The apparent change of shape of a ball is due to its motion.

Equipment and Materials

See text page 257; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. The room should be dark enough—or the light source bright enough—so that the half of the ball away from the light is clearly in shadow. A slide or filmstrip projector makes a good light source. Note that the changing shape of the lit part of the ball is seen only by the child who is moving the ball in a circle around himself. Obviously he represents Earth, and the light from the projector represents the Sun. The children outside this circle, watching him move the ball, do not see the changes in shape that the child moving the ball sees. You may want each child to stand in the light and move the ball around them, to see how the shape of the lit part changes and report their observations. Why does the shape of the lit part change? It changes because the ball is moving around the observer. A child may point out that the shape of the lit part will change if the ball is stationary and the light source moves around them. True enough, but we are considering what happens when observer and light source are not moving.

The light of the Moon. The apparent change in the shape of the Moon is evidence that the Moon is moving around us (around the Earth, that is). But don't we see the Moon move? Doesn't it rise, move across the night sky, and set? Some child may point out that this motion of the Moon is really due to the motion of the Earth, rotating on its axis, which makes the Sun seem to move across the sky each day. You may want to have a globe handy, to confirm the idea.

The Moon is moving in an orbit around the Earth.

A return to the setup in the investigation may help to underline the point that the shape of the Moon does not change for the observers in a spaceship away from the Earth as it does for observers on the Earth. Why not let an observer inside the orbit of the Moon model (the ball) compare what shape he sees with an observer outside the orbit?

Equipment and Materials

. . . mounted globe of the Earth

The face of the Moon. What did men think the Moon was like before the invention of the telescope? There were many speculations, of course. In Galileo's time, only a few hundred years ago, learned men held that the surface of the Moon was perfectly smooth and glassy and round. How did they account for the markings that could be seen on the face of the Moon? They reasoned that the glassy surface was reflecting some features of the Earth's surface. It caused a tremendous sensation when Galileo published a report stating that he had observed the Moon through an improved telescope and discovered that its surface was "full of irregularities, uneven, full of hollows and protuberances, just like the surface of the Earth itself, which is varied everywhere by lofty mountains and deep valleys." [*] Some of the children might be interested to compare Galileo's discovery with photographs taken by spacecraft.

The Moon takes about 28 days to make one complete orbit around the Earth.

Pictures of the far side of the Moon have been taken by television camera from a satellite in orbit around the Moon, and radioed back to the Earth. Perhaps the children would enjoy collecting a series of photographs taken by different space satellites. The horizontal scanning lines of television transmission can be seen in the photographs.

To represent a lunar cycle of 28 days, attach a lump of clay, or some other marker, to a globe to show, approximately, your locality. Set the globe in the center of a circle about 9 feet in diameter. The circle will have a circumference of approximately 28 feet. Then a 1-foot distance on the circumference represents the distance the Moon travels in orbit during an Earth day. Give the globe a complete rotation to represent a 24-hour Earth day, while a child walks the circle, foot by foot. How many times will the Earth rotate before the Moon completes a cycle?

Equipment and Materials

. . . tape measure
. . . globe
. . . clay
. . . rope
. . . chalk

Extending the Concept

The Earth rotates on its axis; does the Moon? Let one child move in a circle around another child, always facing the center of the circle, since the same side of the Moon always faces the Earth. Let other children observe from outside the circle and decide if the moving "Moon" has rotated. Since the observers outside the circle will see different sides of the "Moon" as it moves around its orbit, they must infer that the "Moon" rotates. The child who is moving should make the same inference, since he will have faced all four walls in one complete circling. How many rotations does the Moon make for one complete trip around the Earth? One rotation.

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[*] Quoted in *The Sleepwalkers* by Arthur Koestler, The Macmillan Company, 1959, page 365.

(Text page 260)

Reviewing the Concept

Before You Go On. 1. a 2. a 3. b 4. b

Using What You Know. 1. When we observe a half-moon, the Moon must be at right angles to a line drawn between the Earth and the Sun. 2. To an observer out in space away from the Sun, the shape of the lighted part of the Earth would change, since the Earth moves around the Sun. But an observer at the Sun would see no change.

(Text pages 260–64)

SUBCONCEPT

A comet, like the Moon, may travel in a predictable orbit.

Processes emphasized

Analysis of scientist's methods
Discussion and speculation
Library research
Prediction
Investigation

Section 2: THE VOYAGE OF A COMET

Children relate the appearance of a comet to its orbital motion.

Introducing the Concept

The word "comet" comes from an old Greek word meaning "long-haired." Why was this strange object that streaked across the sky given this name? The illustrations on pages 254, 269, and 270 may help to give the reason. How does the comet remind you of hair streaming in the wind?

You may want to explore this question: How did persons in earlier times feel about the Moon? (Persons wrote songs and poetry about the Moon, and pictured the Moon in tapestries and paintings. In general, the Moon and its light were enjoyed and thought about.) Did the Moon appear regularly or irregularly from month to month? (It appeared regularly; men could chart its appearance and predict both when and where it would appear and the changes in its shape.) How did persons in ancient times feel about a comet? (It appeared unexpectedly and looked like nothing else in the sky. It was not understood because it appeared unexpectedly and then disappeared.) How would you feel about sonic booms (from jet planes), or thunder and lightning, or earthquake tremors, if you did not understand how they are caused? Would you fear them? Or would you seek some explanation between their occurrence and some catastrophe or unpleasant event?

Why don't we fear comets today?

Turn to **The Voyage of a Comet** on page 260.

Developing the Concept

The illustration on page 261 shows a very small section of the famous Bayeux Tapestry, which was woven probably 900 years ago. This one section chronicles the appearance of a comet in the year 1066; in fact, one of the appearances of Halley's comet. Are the men at the left looking with pleasure or with fear at the comet (to the right of the word "stella")? "*Isti mirant stella*" may be translated as "These people are wondering (in awe) at the star." Notice how the artist has shown the comet as a fearsome flaming object. A man is telling King Harold of England about the comet. How has the artist suggested bad news for the king? Shortly after this pictured event, England was invaded by the Normans, and Harold lost his throne to William the Conqueror of Normandy. Today we know that comets are not bad omens, as the unknown artist and King Harold thought.

The comet reappears, Halley finds.

Halley's discovery. The problem that Halley consulted Newton about, charting the orbit of a comet, had defeated some of the best brains of the time. Imagine Halley's surprise when Newton told him that he had solved it, but had not bothered to tell anyone! And imagine Halley's further surprise when Newton couldn't find the papers on which he had made his mathematical calculations.

Let us do some supposing of our own. Let us say that we see the same kind of car going by a certain place every day at the same time, headed the same way. What would you be likely to predict: That it is the same car reappearing, or that it is a different car (of the same kind)? Halley, from his studies, thought it much more likely that the same comet reappeared again and again, and in the same orbit.

Some children might enjoy imagining that they are living next door to Halley and hearing about his idea. Why might they be astonished? They might like to act out their feelings and reactions. One child may act the part of a merchant doing a thriving business selling charms to protect the wearer from the evil effects of comets. Another might present Halley's arguments. Other children might represent bystanders and take sides.

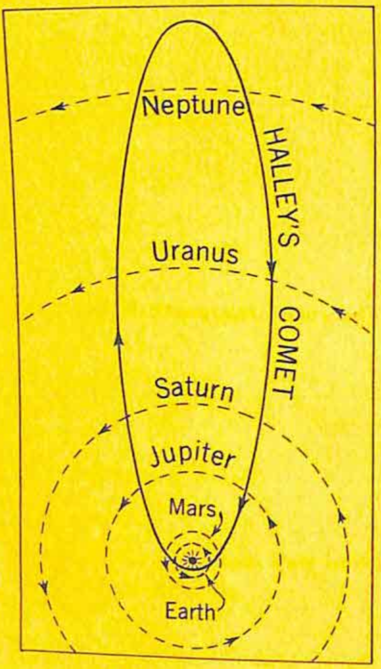
How old will the children in your class be in 1986? When will Halley's comet next appear after that date? (About A.D. 2061.) The visits of Halley's comet have been traced back for over 2,000 years in historical records. The author of this Teacher's Edition knows a person whose father pointed out Halley's comet when this person was about five years old, and he still recalls the comet clearly. Does any child in your class know anyone who saw Halley's comet in 1910?

Some comets do not return.

Halley's comet. Halley's comet revisits the Earth at a certain period as it curves around the Sun. Not all comets are periodic (regular in their return), however; that is, not all comets return. It is impossible to say how many are periodic because some comets may have a very long elliptical orbit. Comets never seen before are found from time to time; an amateur astronomer in a small Ohio town has discovered four within recent years, with the aid of a homemade telescope. Ask the school or public librarian for references which will give more information about comets, and refer to the films, filmstrips, and reading references on pages T-137–39.

A model orbit. As shown in the figure on page 263, only part of the arcs representing planet orbits need be constructed, if you are pressed for space. The string should be stout enough so that it will not give or stretch much. It is worthwhile to try to maintain the same tension as the curve is drawn. The curve will turn out to be an ellipse, approximately the shape of the orbit of Halley's comet, as shown in the margin. The term *ellipse* is introduced in the following section (Section 3); try to let the children find out for themselves what shape the orbit has when they operate the model; so say nothing about ellipses beforehand. Let the children discover what the model does.

Children model the orbit of a comet.



A child may point out that the planets Mercury and Venus are missing in the model. They come in rather close to the Sun on the scale used in this model, which is 100 million miles = 6 inches, or 200 million miles to the foot. If an 18-foot model of the solar system is too great for the space you have available, you might halve the scale distances and the string dimensions.

The orbits of the planets are ellipses, not circles, in fact. On this scale, however, the difference doesn't matter. In 1986 Halley's comet will be curving around the Sun, in view of the Earth.

Extending the Concept

Comet tracking. If orbits are invisible paths, how did Halley discover that three comets followed the same orbit? Astronomers follow the path of a body in space using instruments that combine the work of a compass and a protractor. A model astrolabe can be made from a drinking straw, a protractor, and a paper clip. Tape the straw across the base of the protractor. Tie the string to the middle and weight the free end with the paper clip. On a starry night find the North Star, using a compass if necessary. Sight at the North Star through the straw. The weighted string will fall across the protractor at a figure which is your latitude. If you sighted a comet, the model astrolabe would show the comet's height above the horizon, the compass would indicate the comet's direction, and a watch would tell the time. Some such records enabled Halley to compute comet orbits.

Equipment and Materials

. . . protractor
. . . drinking straw
. . . paper clip
. . . string
. . . tape
. . . compass

(*Text page 264*)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. a 4. b

Using What You Know. People are no longer afraid of comets when they understand what comets are and why they appear.

Section 3: NEWTON AND THE MOON

(*Text pages 264–68*)

Children learn that the pull of gravitation shapes the orbit of the Moon, a comet, or any other body in space.

SUBCONCEPT

The orbit of Halley's comet is an ellipse.

Processes emphasized

Measurement
Observation
Analysis of observations
Hypothesizing
Theorizing
Investigation (with development of a model)
Prediction

Equipment and Materials

. . . chalkboard
. . . chalk
. . . string (for radius of circle)

Introducing the Concept

Halley was able to map out only a small part of the orbit of a comet, just the part visible from the Earth. How could he complete the picture of the orbit, then? Some idea of the method may be given in this way. Have on the chalkboard, when the children arrive, a small circle labeled Earth, and a short section of the circumference of a large curve with the Earth as its center. This section should be short enough so that it is not apparent whether the section is part of a circle or another kind of closed curve. Now, if this short section stands for the observed path of an object in space, can its future path be predicted? No—not enough of the curve is given to predict the complete orbit—if it has one.

If we are told that the orbit is a circle, with Earth at center, can the path be predicted?

Let a child draw a radius from Earth to the given section and complete the circumference. If a small part of a circular orbit is observed, then the whole orbit can be predicted.

Newton told Halley the shape of the orbit of a comet. Knowing this shape, Halley was able to extend the part of the orbit that had been observed, and complete the orbit. Then he could begin to make a prediction.

What shape did Newton tell Halley? Turn to the text, read as far as **Pulling on the Moon,** and do the investigation.

Developing the Concept

It occurred to Newton that the pull of gravitation extended beyond the Earth to the Moon.

The pull of the Earth. Why do we speak of the pull of gravity, instead of gravitation? Gravitation is the more inclusive term; gravity is a special case of gravitation at the surface of a body, such as the Earth or Moon.

There is a pull of gravitation between *any* two objects: between this book and you, for instance. The pull depends on the masses of the objects (the more mass, the more pull), and on the distance between them (the more distance, the less pull). Your mass and this book's mass are so small that the pull of gravitation between them is not noticeable at all. The mass of the Earth is large, however, so the pull of gravitation between your mass (at the surface of the Earth) and the mass of the Earth is noticeable. We call it weight, of course.

Before turning to page 265, you may want to ask the children: If there is a pull of gravitation between the Earth and the Moon, what questions do you think need an answer? (The question is stated on the next page: Why doesn't the Moon fall to the Earth?) The ability to ask questions, to sense interesting problems, is a very important one in science. No problem can ever be solved unless the right question is asked. If the question does occur to some of the children, you can pose the question and accept hypotheses for answers. Then turn to the text and investigation for evidence.

An object in motion tends to move in a straight line.

Equipment and Materials

See text page 267; also the Teacher's Manual for *Classroom Laboratory 4.*

The investigation. A tennis ball is easy to tie thread to, but any ball will serve. The larger the ball, the more marked the results will be. The floor must be smooth and flat enough not to disturb the path of the rolling ball. You will find that thread, or even light string, will not interfere with the rolling of the ball if the thread is kept slack; and the ball will roll in a straight line. To make the ball move in a curve, what is needed? A steady pull on the string. The ball must be forced to move in a curved path, for an object in motion tends to move in a straight path.

If the thread is shortened, the curve is made sharper, and a greater pull is needed to make the ball go in a sharper curve.

Equipment and Materials

. . . eraser or other soft object
. . . string

There is a variation that you may wish to encourage a child to demonstrate. Tie a soft object like an eraser, a sponge, or a bean bag, to one end of a 2-foot string. Swing the object around above the head, at the end of the string. What is the shape of its orbit? Make a drawing on the chalkboard. Now swing the object again, but let go of the string. Of course, do this only where the object can fly off in a safe direction. What is its orbit now? Show on the board. When the string is released, the eraser flies off in a straight line, tangent to the circle. There are no strings that keep the Moon circling around the Earth. Something seems to, however. What does pull the Moon around the Earth in a curved path? (The pull of gravitation.)

The pull of gravitation between Earth and Moon shapes the Moon's orbit around the Earth.

Pulling on the Moon. How do we know that the Moon is moving? What evidence do we have? (The evidence of the changing shape of the lit part of the Moon, discussed in Section 1.) The pull of gravitation keeps the Moon moving around the Earth instead of doing what? (Instead of moving in a straight line off into space.)

Comets that make return visits to the Sun (and Earth), like Halley's comet, have elliptical orbits. A comet may take several thousand years to make the round trip. Or its orbit may not be an ellipse, but a parabola or a hyperbola, a curve that is open on one end on a plane surface. The comet is pulled in a curve by the Sun's gravitation, but not in enough of a curve to make the comet return. So the comet disappears into outer space again. However, the orbit of an object in space moving around another and pulled by gravitation—the Moon around the Earth, or a manned satellite around the Moon, or a planet or comet around the Sun—is an ellipse.

Extending the Concept

Action of an outside force. The rolling ball in the investigation tends to travel in a straight line and has to be forced to move in a curve. When a ball is traveling in a straight line across a smooth floor, does it tend to stay in motion, or does it tend to stop? How does a thread tied to the ball show that a pull must be used to make the ball stop? (Bring the rolling ball to rest by pulling the string.) If a rolling ball tends to keep on going, what makes it slow down and stop eventually? (The pull, or drag, of friction brings the ball to a stop.) Newton clearly stated the behavior of moving objects. He said that a body in motion tends to remain in motion, in a straight line, and with undiminished speed—unless the body is acted on by an outside force. This is an important part of one of Newton's famous Laws of Motion.

(*Text page 268*)

Reviewing the Concept

Before You Go On. 1. a 2. a 3. b 4. b

Using What You Know. 1. A spaceship very near the Moon might be drawn to the Moon by the pull of the Moon's gravitation. 2. The orbit will have the shape of an ellipse, because this is the shape that the pull of gravitation gives to any object moving around the Sun.

Section 4: COMETS AND SOME OTHER SPACE TRAVELERS

(*Text pages 269–74*)

SUBCONCEPT

Meteors may be fragments of disintegrated comets.

Children study the makeup of comets and meteors and learn that one may be the source of the other.

Processes emphasized

Measurement
Hypothesizing
Theorizing
Prediction
Observation
Analysis of observations

Equipment and Materials

- . . . chalkboard or large sheet(s) of paper
- . . . chalk or crayons
- . . . ruler

Introducing the Concept

If a child or two can draw on the chalkboard (or on a large piece of brown paper) a rough facsimile of the orbit of Halley's comet as shown on page T-144, you may want to ask, where is Halley's comet now? You won't get a good answer, for even a rough approximation is difficult to make; but the children may get some picture of how the speed of a comet varies along the orbit. Is Halley's comet outward bound or on the return trip? (We can be sure that it is on the return trip to the Sun, since more than half of the 76-year round-trip time has gone by.) Where is the comet along the return side of the orbit, then? If anyone suggests working it out according to the proportion of time gone by, and time to go, you may point out that the speed of a comet is not constant around its orbit; the speed varies. The farther the comet is from the Sun, the slower it travels; and the nearer it gets to the Sun, the faster the comet goes. In fact, at its greatest distance from the Sun, beyond the orbit of the planet Neptune, Halley's comet loafs along at 4 or 5 miles per second. When it is making its sharp turn around the Sun, the comet takes the curve at about 200 miles per second. With this in mind, a rough approximation is acceptable. Of course, if there is an astronomer within call, amateur or otherwise, the children might call upon him and ask him for further information.

What is a comet, really? What are they made of? Do they give off their own light, or are they seen by reflected light? Do they go on forever?

Read through page 270, and plan the investigation.

Developing the Concept

The head of a comet is a mixture of ice and rock.

A ball of ice. The illustrations of comets on text pages 254 and 270 can be used for identifying heads and tails, as well as the one on page 269. Did the artist who made the section of the Bayeux Tapestry (page 261) know that a comet has a head and tail? (He did, and improved on the idea.)

Why does a comet's tail stream away from the Sun? You can cast out a somewhat difficult clue, if you see fit: Didn't we learn that light sometimes behaves like waves, sometimes behaves like a stream of particles (Unit Two, Section 5)? It is the pressure of the Sun's light against the incredibly thin gas that the tail is made of, that swings the tail away from the Sun. This is one instance in which light behaves as if it were a stream of tiny particles rather than waves.

Meteors do not appear at regular times.

The investigation. How many of you have seen "shooting stars"? When, and where? Do you know any sayings about shooting stars? Your library may have some references containing more meteor shower time tables, incidentally. During a given meteor shower the meteors may all seem to come from one direction; but otherwise, directions of showers vary, as do brightness, color, and duration of individual or groups of meteors.

Friction of a meteor against the atmosphere results in heat and light.

A streak of light. Some meteors have been so bright that they have "turned night into day," as the saying goes. Some have appeared to the eye to be as large as the Moon, in angular size. When a meteor enters our atmosphere, the friction between the surface of the meteor and the molecules of the atmosphere generates heat. The heat is so great that molecules leap from the surface of the meteor. These escaping molecules collide so violently with molecules of the atmosphere that light energy is given off. This is the light we see.

Extending the Concept

Meteorite craters. The crater shown on page 273 is the Berringer Meteor Crater near Flagstaff, Arizona. Children may enjoy using several references to get a more complete story of how this huge crater was formed. The Chubb Crater in Canada is still larger; what is its story?

(Text page 274)

Reviewing the Concept

Before You Go On. 1. b 2. a 3. a 4. b 5. b

Using What You Know. Rocks in space, small or large, might penetrate a space capsule.

Section 5: WHEN SCIENTISTS PREDICT

Children learn that scientists can make predictions about the relation of bodies in space.

(Text pages 274–77)

SUBCONCEPT
The shape of orbits and the position of bodies in space are predictable.

Introducing the Concept

Show the class a table tennis ball and ask, "Can you predict what will happen if I drop this ball on the table?" They will predict that the ball will bounce, of course. Lead them up this false trail a bit farther; hold the ball a few inches above the table. How high will the ball bounce? Raise the ball a foot or two higher. How high will it bounce now? The predictions will be that the ball will bounce almost as high as the point from which it's released. Are all predictions in? Then drop the ball, from a height of about a foot. It lands with a thud and bounces not at all, since you have filled it with water beforehand. (To set up your problem, make two holes with a large-diameter needle, one at the top and one at the bottom of the ball. Hold the ball under water; tapping it on the bottom of the container will speed the water entering and air leaving. It is not necessary to fill the ball completely; a ball about half-full of water will behave well. Seal the holes with small pieces of transparent tape or with a dab of cement.)

Why didn't the ball bounce? Let the class hypothesize before you reveal anything. Why didn't the predictions work? (There wasn't enough information.) Do you have to have information, then, to predict?

What does "to predict a happening" mean?

What kinds of predictions do you know of? (Weather, sports, eclipses, etc.) The way is open for a discussion of prediction. References to dictionaries may be in order. Do scientists make predictions? They do indeed. How? After sufficient discussion, turn to text page 274.

Processes emphasized

Observation
Analysis of observations
Hypothesizing
Theorizing
Prediction
Library research

Equipment and Materials

. . . table tennis ball
. . . water
. . . transparent tape or plastic cement
. . . needle

Developing the Concept

Knowing what makes it work. You may want to bring forth another table tennis ball (this one untreated) to stress the point that knowing what makes it work is a basis for prediction. What will happen if you drop the ball? (The predictions will be more cautious this time, probably.) Why does the ball bounce? What makes it work? (When the ball hits, it is pressed out of shape, pushed in.) But the material returns to its normal shape very quickly. This is what is meant by elasticity; the material is elastic. So long as the substance of which the ball is made has elasticity, the ball will bounce. We can predict that the ball will bounce so long as it has elasticity. (Putting water in the ball interfered with the elasticity.) Show a ball of modeling clay. What is your prediction? Will this ball bounce? You can predict that it will not bounce, not because such balls have never bounced in the past; but because the material is not elastic, it will not retain its shape, after it has been forced out of shape.

Prediction should be based on understanding.

Equipment and Materials

. . . table tennis ball
. . . ball of modeling clay

The gravitational pull of Jupiter may affect Halley's comet.

The tardy comet. Jupiter is the largest of the planets. Its mass is about 318 times the mass of the Earth. (Saturn, the next largest planet, is about 95 times the mass of the Earth.) So the gravitational pull of Jupiter on Halley's comet can be greater, over a given distance, than the pull of any other planet.

The gravitational pull of a planet can do more than slow down or speed up a comet; it may cause the comet to swerve around into a new orbit. A comet coming into the solar system from outside may be drawn into an orbit around the Sun in this way. Or a comet in orbit around the Sun (like Halley's comet) might be pulled out of that orbit by a passing planet, and travel out of the solar system.

Equipment and Materials
. . . a world almanac

In the astronomy and calendar sections of a world almanac children will find many predictions. Which of these predictions are based on scientists' understanding of what shapes the orbits of the travelers in space?

Extending the Concept

Some famous predictions. Children may have read Mark Twain's book, "A Connecticut Yankee in King Arthur's Court," or may have seen it dramatized on television or in the movies. Do they remember how the ingenious stranger at the court of King Arthur saved his own neck by predicting a total eclipse of the Sun? Similarly, Columbus secured food by threatening reluctant Jamaicans. He had read in his almanac that there would be a total eclipse on February 29, 1504. As the Moon blotted out the Sun, the natives came running with the wanted supplies, begging Columbus to restore the light.

(Text page 277)

Reviewing the Concept

Before You Go On. 1. Scientists can predict the positions of the Moon and the Earth because they know their orbits and speeds and understand what causes them. 2. The time of return of Halley's comet can be predicted because the shape and size of its orbit and its speed are known. 3. When Halley's comet is slowed down by the gravitational pull of Jupiter, scientists can predict that the comet will be late.

(Text pages 277–79)

CONCEPTUAL SCHEME
The universe is in constant change.

UNIT CONCEPT
The motion and the path of celestial bodies are predictable.

What concepts have been formed from this unit?

Section 6: THE MAIN CONCEPT: REGULAR CHANGE

Children begin to understand that, although the Earth, the Moon, the planets, comets, and other celestial bodies are always moving, always changing position, scientists have found unchanging order in these changes.

CONCEPT SUMMARY

The class might turn again to the illustration and text on pages 254 and 255. "What makes us think that this comet will appear again?" "What makes us think that it will appear at a certain time?" Now the answers to these questions will surely differ from the responses offered when the unit was begun. Then the children probably appealed to the authority of science: "Scientists know . . ." "Scientists say . . ." Now the children have glimpsed the methods of scientists exploring the skies, and the evidence scientists have found. Now the children can say, "Scientists say that Halley's comet will return *because* . . ." Concepts concerning the nature and methods of science have been further developed, in other words.

Why does the shape of the Moon change?

Whatever the changing shape of the Moon was to a child before, it is now something more. It is evidence that there is motion out in space, that the Moon is moving around the Earth, not standing still. Moreover, the path of the Moon as it moves is known. The Moon moves in a definite orbit, in a regular way. There is change, but there is regularity; there is order in the change.

Why were comets feared?

Out of the story of Halley and Newton, and the solving of the problem of how comets suddenly appear and disappear, is formed the concept of another body in space, changing yet orderly. But there is more; there is the concept of science as a weapon against fear. Comets were feared because they were strange intruders in the sky, mysterious, not understood. Scientists, Halley and Newton foremost among them, helped do away with that fear. Newton's bold guess, that the pull of gravitation extended beyond the Earth to the Moon, beyond the Moon among the Sun and planets, beyond the solar system into the universe, extended man's understanding as well. Those mysterious streaks of light, "shooting stars," were brought within the range of understanding too.

Where there is change, can there be order?

Along with this concept of continual change taking place among the celestial bodies, there develops the concept of order in the changes. The Moon, comets, and other celestial bodies are in motion, but we find order in these motions. We can map the paths these space travelers follow. We can time their comings and goings. More than that, we can account for their behavior, at least in part. And so we can predict their behavior, also, at least in part. We find that the motion and path of celestial bodies are predictable.

FIXING THE MAIN CONCEPTS

(*Text pages 278–79*)

Testing Yourself. **1.** b **2.** a **3.** a **4.** b **5.** b **6.** a **7.** b **8.** b **9.** b **10.** b

(*Text pages 280–83*)

CONCEPT RELATIONSHIPS

Change is constant. Living things change; the Earth and all the other bodies in space are constantly changing.

A NEW VIEW OF CHANGE

One does not need to look at a mountain to observe the forces that are wearing down the surface of the Earth. Those forces are at work all around us. In the town or city, for instance, the stone of buildings is weathered and eroded, changed by the forces of wind and water and air. Plants force their way up through cracks in sidewalks. Holes appear in the surfaces of roads, started by expansion and contraction due to heat and cold, enlarged by the action of wheels. Chemical action by substances in the atmosphere breaks down some materials while forming others. Miniature gullies are cut into lawns and driveways by running water, and the soil and rock that the water carries off is laid down in some other place, building up the land there.

The surface of the Earth is being worn down and built up by wind and water and air; the surface of the Earth is changed by men, too. Men take away forests, strip cover from the soil, let soil be carried off by wind and water. Men take minerals from the ground. Only recently, really, have men become aware that the forests and the grass (and the animals that lived in them), and the minerals, are not endless. What can men do, and what are men doing, to balance such changes?

TEACHING SUGGESTIONS

Changes in living things are continual.

Living things change. Not only is the surface of the Earth continually changing but the living things on the Earth are continually changing. What is one way by which we know that living things were different in the past? Fossils have given us evidence that living things have changed. Are living things changing now? The forces that made living things change in the past are still at work. Living things are changing now—slowly, but changing.

Are men making changes in living things, too? Men make changes in plants; they produce new varieties of corn, new kinds of wheat, new fruits and flowers. Men make changes in animals; they produce hens that lay more eggs, horses that run faster, cows that give more milk. Men are changing the surface of the Earth and the living things on the Earth. By comparison with the changes that nature has made, the changes that men have made are puny, to be sure. But would you say that men's power to make changes is decreasing or increasing?

Some changes are part of a cycle; others are not.

Changes you can see. Some of the changes you can see are part of a cycle; some are not. For example, melting ice becomes water, water becomes water vapor. What happens to the molecules of water vapor? They may return to the form of water, or ice, as part of the water cycle. When you rub your hands together, however, something different happens. Mechanical energy (rubbing hands) is converted to heat energy. What happens to this heat energy? Eventually it passes into the atmosphere, into the air. Can we capture it again and make it do some useful work? No, this energy is not part of an energy cycle.

Usefulness of the concept of change.

Understanding change. We live on a changing planet, among changing living things, in a changing universe. So did dinosaurs, once. What happened to the mighty dinosaurs? We are not sure why, but they died out. They disappeared. One thing is sure: some changes took place, on this changing planet, that the dinosaurs were not able to cope with. So dinosaurs ceased to live on this planet.

Could that happen to man?

Not if he has sufficient understanding, understanding that brings power to predict, prediction that brings power to control, control that brings power to make the world a better place to live in—a place where men may reach their full stature.

ON YOUR OWN

PROBING WITH A MICROSCOPE

(Text pages 284–99)

You can direct a questing child to this end-of-book section when you see fit; no prerequisite study of the text is needed. Indeed, it may work the other way 'round: the young microscopist may find himself studying the text so that he can understand what he sees in a drop of water. Of course, all children will benefit from a study of this section.

If you feel that you are not well enough informed in this area to act as a guide, you might look about for some other teacher (perhaps in junior high or high school) at whom the child may aim his inevitable questions. Just the same, the child will appreciate your interest and encouragement. You may have to acquaint him with a well-established law of scientific research usually known as Murphy's Law: If anything can go wrong, it will. Persistence can offset the operation of Murphy's Law, but persistence usually has to be developed. It comes from encouragement, the kind of encouragement that you know best how to give.

Investigations are suggested and problems posed in this section, but with the hope of being provocative rather than prescriptive. No one should feel bound by them. The child who finds that he can make up his own problem makes a real discovery. On the other hand, the child who struggles to catch one paramecium in the act of becoming two, and does so, has also discovered something, not about paramecia but about himself and his power of achievement.

UNIT EIGHT

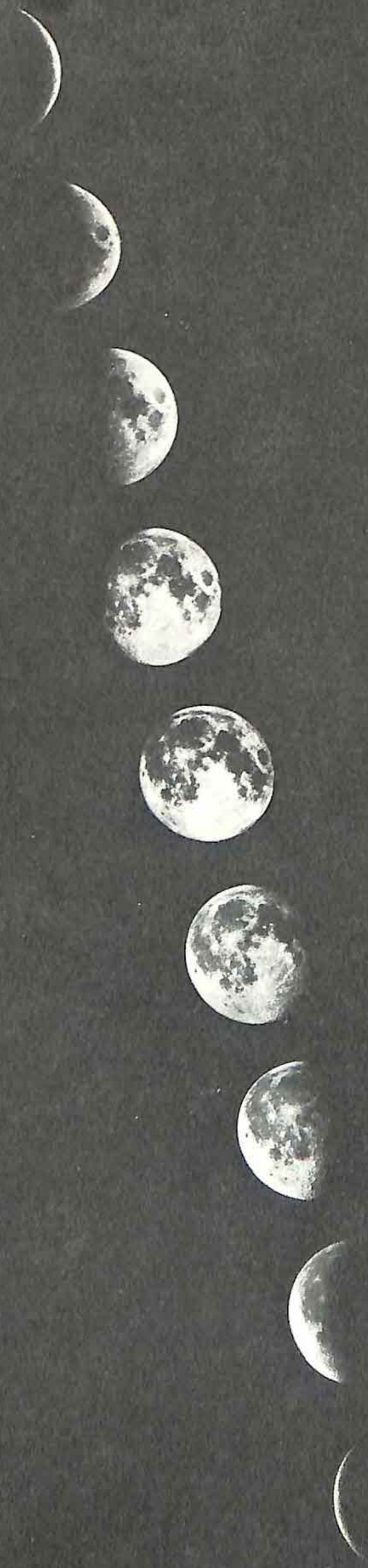
THE VOYAGE OF HALLEY'S COMET

The year is 1910. People look with wonder at the strange object in the night sky. It is Halley's comet, moving across the background of stars. In a few weeks it vanishes. But people who are there remember it for the rest of their lives.

If you had been there in 1910, you would not have forgotten it either. You won't when you see the comet in 1986.

What makes us think that this comet will appear again? What makes us think that it will appear at a certain time?

The answer begins with a look at the Moon.



■

1. The Voyage of the Moon

Everyone has noticed that the Moon always seems to be changing shape. The changes happen over and over again, so often that we do not usually pay much attention to them. If you could observe the Moon night after night for a few weeks, you would see that its shape changes like this. See the pictures marked at the left. ■ These changes are repeated over and over, in a cycle. It takes the Moon about 28 days to go through one cycle; that is, it takes this time for these changes.

We do not pay much attention to this cycle. It just happens, and goes on happening, whether we pay attention to it or not. But let us ask ourselves *why* the Moon's shape seems to change. These changes tell us some interesting things about the Moon, the Earth, the Sun, and about other bodies in space as well. What do these changes in the shape of the Moon mean? See for yourself by doing the investigation opposite.

The Light of the Moon

Look at the changing shape of the ball in the investigation. Look at the changing shape of the Moon. The shapes are alike, aren't they?

AN INVESTIGATION into Seeing a Lighted Ball

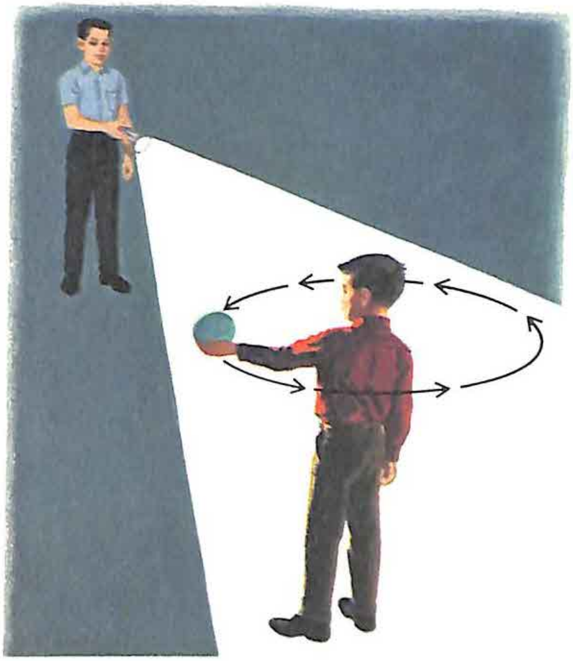
Needed: a flashlight, a ball, a dark room

The darker the room is, the better. Let someone hold the flashlight so that you can stand some distance away from it but in its light. Hold the ball in your hand, like this. ■ Now turn slowly so that the ball moves in a circle around you. (Raise the ball to keep it out of your shadow, if necessary.)

What happens to the shape of the lighted part of the ball?

Now hold the ball in each of these positions. ● Draw the shape of the lighted part of the ball, as *you* see it, in each position.

Why does the shape of the lighted part change?



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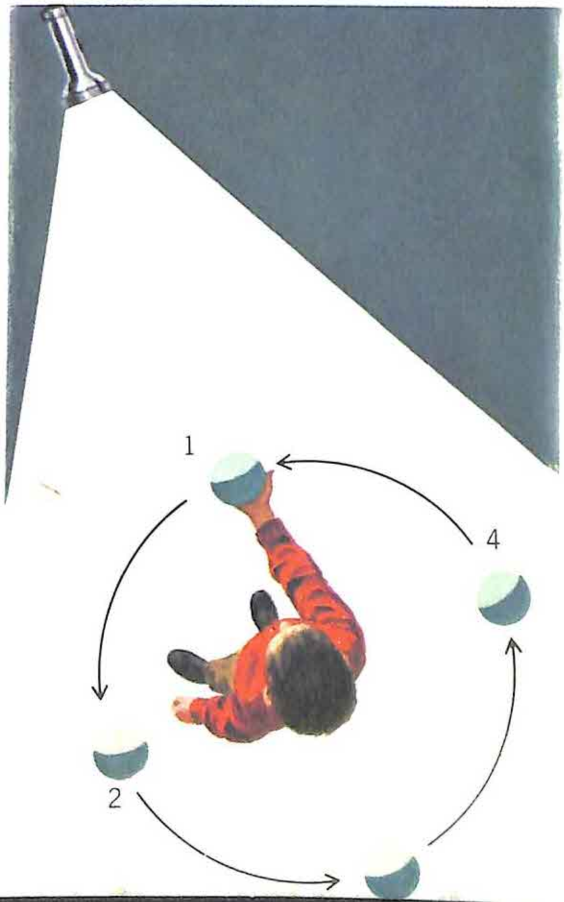

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The shape of the ball does not really change. It remains a ball. What *does* change is the shape of the lighted part.

Why does the shape of the lighted part of the ball change? *The shape changes because the ball is moving.* As the ball moves around you, the shape of the lighted part changes.

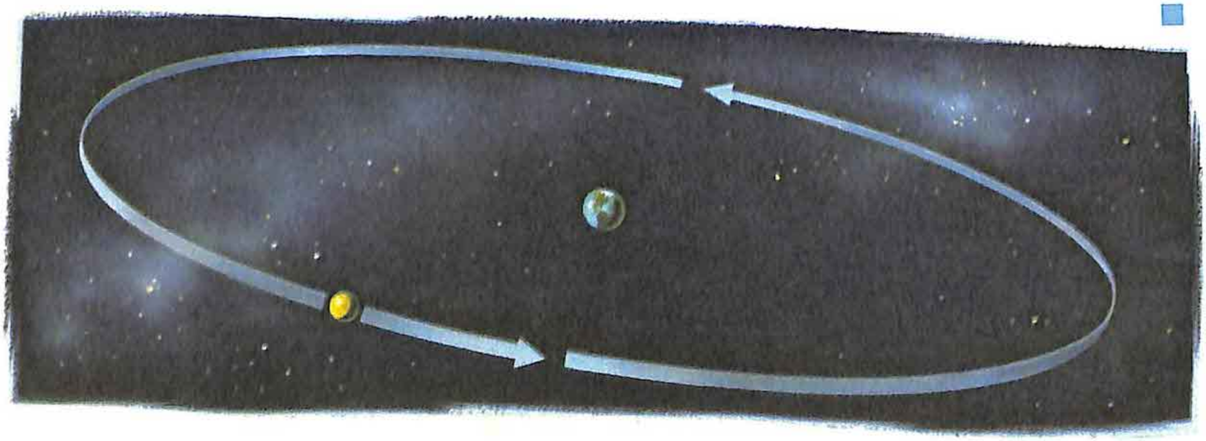
Why does the shape of the lighted part of the Moon change? The shape changes because the Moon is moving. The Moon is moving around you, much as the ball moved around you in the investigation.

Let us take a look from a distance at our Earth and its Moon. Imagine that we are in a spaceship about 100,000 miles away from the Earth. We look back at the Earth and its Moon. What do we see?

We see that the Earth and the Moon are lit by the far-off Sun. As we watch, we see the Moon slowly moving around the Earth. It takes about 28 days to make one trip around the Earth. It follows the same path around the Earth each time. We call this path in space an **orbit.** The Moon is in an orbit around the Earth. ■

We see, too, how the shape of the lighted part of the Moon changes. When the Moon is off to one side of the Earth, it seems to be a **half moon** to someone on the Earth. When the Moon is on the far side of the Earth from the Sun, it seems a **full moon** to someone on the Earth. And the **new moon** is on the same side of the Earth as the Sun.

Let us get down to Earth again. There is something else we can observe about the Moon from the Earth. However, as we see the changing shape of the Moon in the sky, from night to night, we now know what that changing shape



means. The changing shape of the Moon means that the Moon is moving.

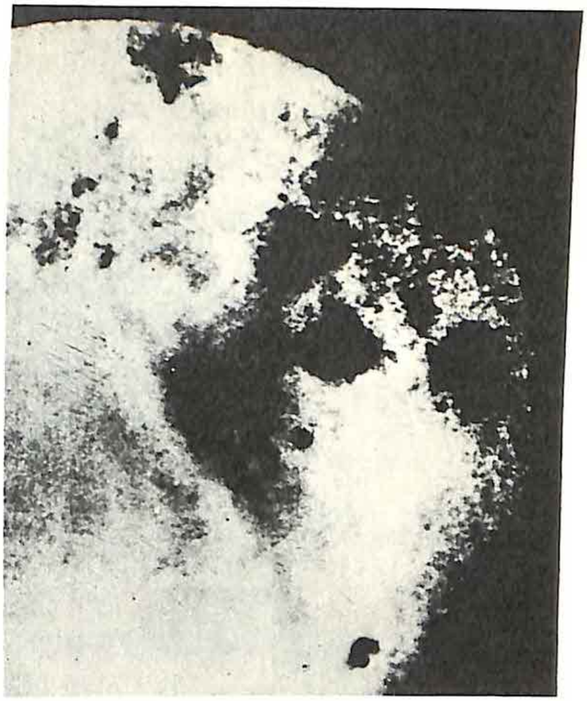
The Face of the Moon

Look again at the photographs of the Moon, on page 256, but this time look closely at the Moon's face.

Does the face of the Moon change as the Moon is following its orbit around the Earth? It does not, as you can see. The face of the Moon does not change, because the Moon always has the same side toward us. As the Moon moves in an orbit around the Earth, it keeps the same side facing the Earth.

Ever since men have known this, they have wondered what the other side of the Moon was like. Was it very different from the side we see? When a satellite traveled around the Moon and took photographs of the other side, we discovered that the other side of the Moon seems to be much the same as the side we see.

The changing shape of the Moon in the night sky reminds us that the Moon is moving. The Moon is moving, moving in an orbit around the Earth, moving silently through space.



You may know that scientists of several countries are interested in what the Moon is like. For example, on March 23, 1965, the United States Ranger 9 rocket sent back television pictures of an area of the Moon. This was the third time the United States had done this. To obtain pictures, the scientists had to be sure the Moon would be in the right position before the rocket was launched.

What does the moving Moon have to do with a **comet,** a heavenly body with a tail of glowing matter? What has the moving Moon to do with a comet that is supposed to appear in 1986, Halley's comet?

Let us return to Halley's comet and see.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. The Moon has a cycle which takes about
   a. 28 days
   b. 14 days
2. In its cycle the lighted part of the Moon which we see
   a. changes its shape
   b. does not change its shape
3. The path of the Moon around the Earth is called
   a. a shape
   b. an orbit
4. The changing shape of the Moon reminds us that the Moon is
   a. far away
   b. moving

USING WHAT YOU KNOW

1. Where is the Moon in its orbit when we see a half moon?
2. The shape of the Moon itself does not change. The shape of the lighted part of the Moon changes. Does the shape of the lighted part of the Earth ever change? How do you know?

ON YOUR OWN

Are you reading about man's attempts to reach the Moon? Keep a scrapbook of newspaper and magazine clippings on "Project Moon."

2. The Voyage of a Comet

People used to be afraid of comets.

A comet, you see, was something that did not seem to belong in the sky. The stars seemed to be always in their places, fixed and unmoving. The planets and the Moon all moved, to be sure. Yet they moved in regular ways and in the same orbits all the time. You could count on their regular behavior.

■

Then suddenly a comet might appear. A comet looked like nothing else in the sky. Sometimes it was strangely bright. It moved across the sky and in a few weeks disappeared. Where did a comet come from? Where did it go? No one knew. It frightened people. They felt that a comet was a sign that something bad was going to happen: war, disease, floods, or who knew what? ■

Comets used to be feared. A man named Halley changed that.

Halley's Discovery

Edmund Halley was an English scientist who lived over 200 years ago. ● He was interested in many things, but he was especially interested in comets. Where did comets come from, and where did they go? Halley wanted to know. He studied the observations of comets, which other scientists had made. The orbit of a comet was a very difficult problem in mathematics. He could not figure it out. Neither could other scientists who tackled the problem.

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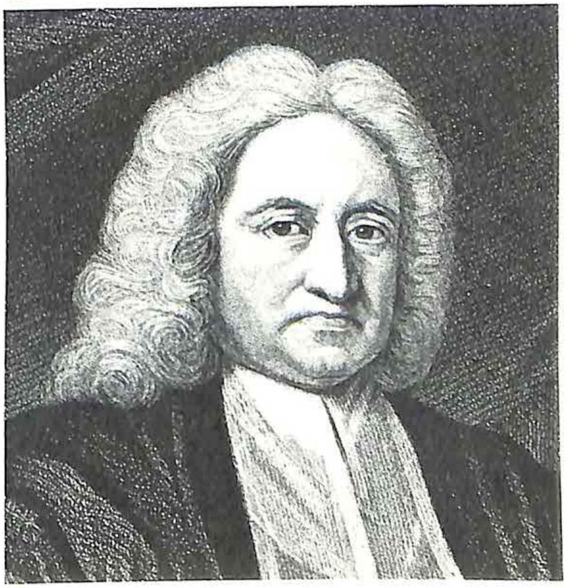


However, Halley had a friend named Isaac Newton, who was a brilliant mathematician. Could Newton possibly figure out what the orbit of a comet would be like?

Yes, he could. In fact, he had already worked out that problem, Newton thought. But he could not find the papers on which he had done it. He would work it out again. Presently Newton showed Halley what shape the orbit of a comet would have.

Now Halley set to work. He figured out the orbits of some of the comets that had been observed by scientists. He made a surprising discovery. The comets that had appeared in the years 1531, 1607, and 1682 had the same orbit.

It seemed very strange to Halley. Three different comets following the same orbit, the same path in space? The more Halley thought about it, the more he thought that there had not been three different comets, as people thought. He decided that they had simply seen the same comet three times. *The comet had gone away and had come back again.*

It was an astonishing idea! Halley felt certain enough to make a prediction of what would happen in the future. He predicted that this comet would appear in the year 1758.

The same comet had appeared, if Halley was right, in 1531, in 1607, and in 1682. Its appearances had been 75 to 76 years apart, then. Halley predicted that the comet would return 76 years after its last appearance. It would appear in 1758.

Halley's Comet

Remember, no one had ever predicted the appearance of a comet before. Remember that comets were thought of as strange and wild and frightening things. Moreover, there were 53 years to go before Halley's prediction could be tested.

In 1758 the comet appeared in the sky. Halley had been right. Halley did not see it, for he had died some years before. Ever since then that comet has been called Halley's comet, in his honor. Since then, Halley's comet has returned at the predicted times. It will return, we can predict, around the year 1986.

We do not fear comets any more. Halley's discovery made comets a part of the sky, like the stars and planets and Moon. What is the orbit of Halley's comet? Where does it come from, and where does it go? Make the model on the opposite page. It will give you an idea of the voyage of a comet.

MAKING A MODEL: The Orbit of a Comet

Needed: about 34 feet of heavy string, chalk, masking tape, a yardstick, and a large clear floor or playground

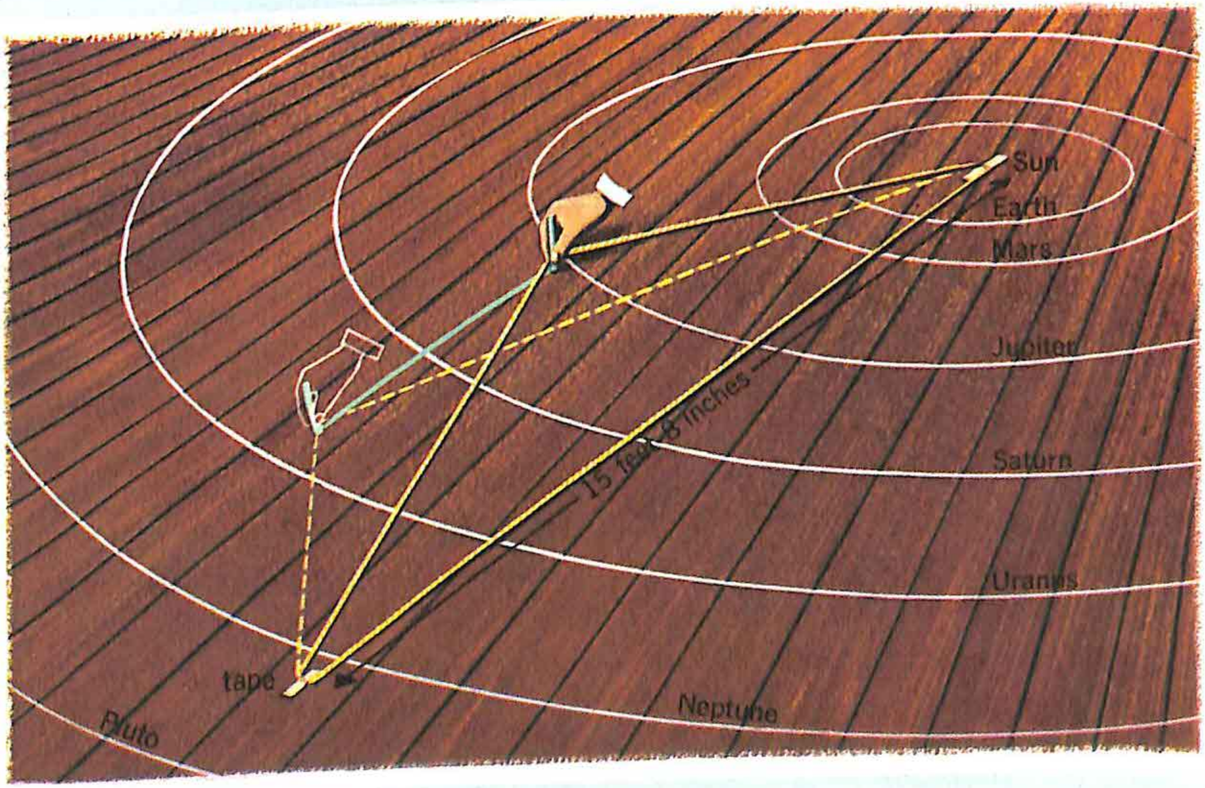
First make a scale model of part of the solar system. Mark a spot in the center for the Sun and draw circles to represent the orbits of these planets:

Earth	radius of $5\frac{5}{8}$ inches
Mars	radius of $8\frac{3}{8}$ inches
Jupiter	radius of 2 feet 6 inches
Saturn	radius of 4 feet 6 inches
Uranus	radius of 9 feet 0 inches
Neptune	radius of 14 feet 0 inches

Make a loop of the string that is just 16 feet 2 inches long. Tape the loop to the floor at the Sun and 15 feet 8 inches stretched out from the Sun, as shown below. ■

Now hold the chalk inside the loop and against it, as shown. Move the chalk along the loop, keeping the string taut. It will trace an orbit like that of Halley's comet, swinging around the Sun and out into space beyond Neptune's orbit, and back.

Where should Halley's comet be on this model in 1986?



BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. Edmund Halley had the help of the mathematician
   a. Charles Darwin b. Isaac Newton
2. Like the Moon and Earth, comets have
   a. an orbit b. a spherical shape
3. Three comets which appeared about 76 years apart had the same orbit. Halley said they must be
   a. the same comet b. different comets
4. Scientists can predict when some comets will appear because they can calculate some comets'
   a. shapes b. orbits

USING WHAT YOU KNOW Why are people no longer afraid of comets?

3. Newton and the Moon

Halley figured out the orbits of other comets besides the one that bears his name. You may remember, however, that he first had to ask his friend Newton what the orbit of a comet was like. Halley could not solve the problem of the orbit, nor could any other scientist except Newton. He had already solved the problem, but he could not find his papers, you recall. He had to work out the answer again.

What did Newton tell Halley? Newton told Halley that the orbit of a comet had the shape of an **ellipse** (ih·LIPS). An ellipse is the shape of a flattened circle. Here are a few ellipses. ■ The orbit you made in the investigation on page 263 is an ellipse.

How did it happen that Newton was able to answer Halley's questions? How did Newton know that the orbit of a comet is an ellipse? He knew because he was a careful observer and thinker.

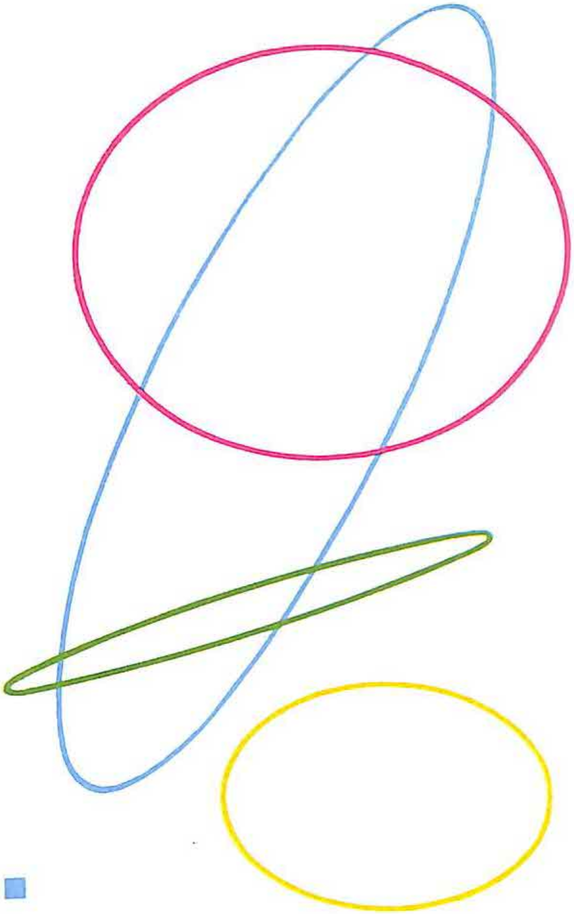
The Pull of the Earth

Throw a ball straight up. It slows down, it stops for a moment, then it starts back to the ground. It seems to be *pulled* to the surface of the Earth. Anything that you throw into the air will act in the same way. It will always go up, stop, and then fall back to the ground.

Let go of a pencil, a coin, a rock, this book. They fall to the ground. They seem to be pulled to the surface of the Earth. Hold this book in your hand. You can feel the pull of the Earth on the book.

It doesn't matter where you are. If you are at the top of a tall building or a cliff, any object you drop will always fall to the ground.

The Earth has a pull on every object on the Earth. We call this pull **gravitation** (grav·ih·TAY·sh'n). It is the pull of gravitation that makes objects fall to the ground. It is the pull of gravitation that holds objects to the ground, and holds you, too. When you have to lift an object, the pull you lift against is the pull of gravitation. Gravitation pulls everything on Earth. In fact, gravitation pulls on things near the Earth, too, as you know. Balls and birds, kites and airplanes, are pulled down by gravitation.



When you look at the Moon calmly sailing through the night sky, you might not think of gravitation. Isaac Newton did. Newton had an idea that the pull of gravitation reached out from the Earth to the Moon. He showed that the Moon is being pulled to the Earth by gravitation, just like other objects.

Balls and birds, kites and airplanes, are pulled down by gravitation. So is the Moon, said Newton. This poses another question, however.

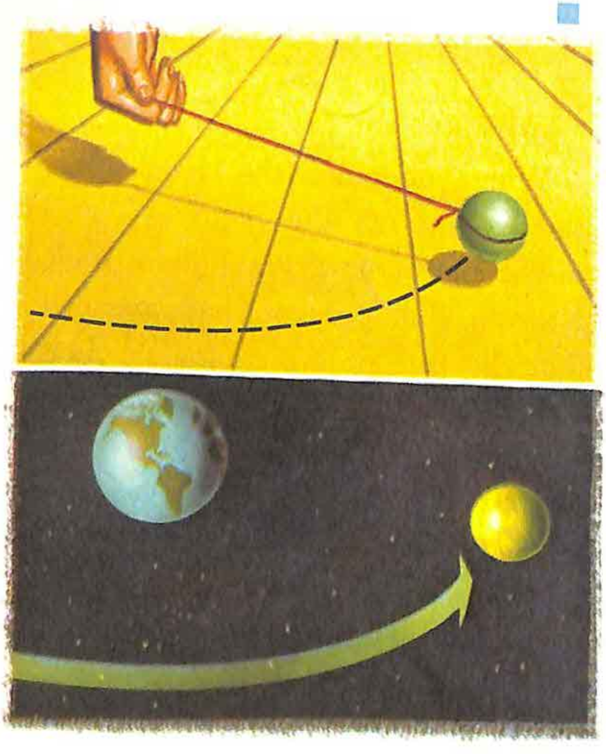
If the Moon is being pulled to the Earth by gravitation, why doesn't the Moon fall to the Earth?

You can get a clue to the answer by trying the investigation on the opposite page.

Pulling on the Moon

The Moon is moving. It would move away from the Earth, except for the pull of gravitation.

A ball rolling along a level floor moves straight ahead. To make the ball go in a curve, it must be *pulled* around. It is the pull of the thread that makes the moving ball go in a curve around your hand. It is the pull of gravitation that makes the moving Moon go in a curve around the Earth.



What happens if you let go of the thread tied to the moving ball? The ball rolls away. What would happen to the Moon if the pull of gravitation stopped? The Moon would sail away from the Earth, into space.

The Moon is pulled by the Earth's gravitation. However, the Moon does not fall to the Earth because the Moon is moving. It would move away from the Earth, except that the pull of gravitation keeps it curving around the Earth.

It was Isaac Newton who worked out these ideas about the Moon and the Earth and gravitation.

Newton did something more. He figured out, by mathematics, what sort of orbit the Moon has. He found that the orbit of the Moon around the Earth is an ellipse. In fact, he found that the orbit of any object moving around another and pulled by gravitation is an ellipse. The orbit of a comet is an ellipse. That was what Isaac Newton told Edmund Halley.

Halley was able to understand what Newton was talking about. The concept of gravitation helped him to predict that the comet he was studying would return at the time it did.

AN INVESTIGATION into a Moving Ball

Needed: a tennis ball, about 3 feet of strong thread, a smooth, level floor

Tie one end of the thread to the tennis ball. ■

Hold the other end of the thread in your hand and roll the ball along the floor. *Keep the thread slack.* Does the ball roll in a straight line or in a curve?

Here is what happened in one trial. ●

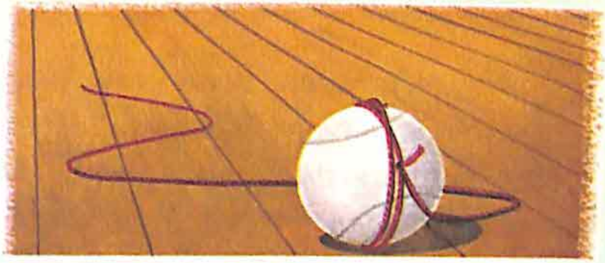
Now hold the end of the thread to one place on the floor. *Keep the thread taut.* ▲ Roll the ball. Does the ball roll in a straight line or in a curve?

Here is what happened in one trial. ◆

What do you feel in the string as the ball rolls in a curve?

To make the moving ball go in a curve, what is needed?

Additional Investigation: Try using a shorter length of thread. What happens to the curve? What happens to the pull? Is more pull or less pull needed to make a sharper curve?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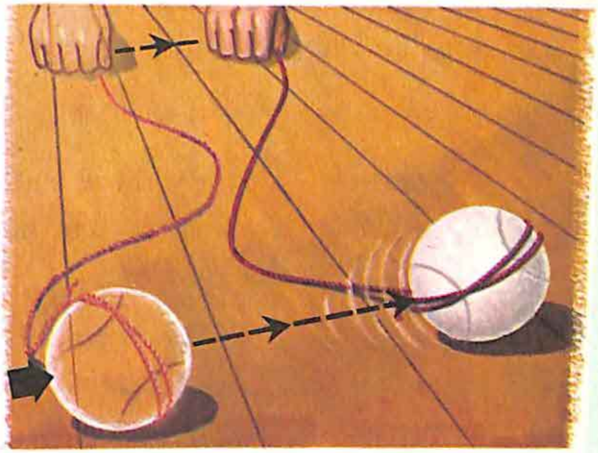
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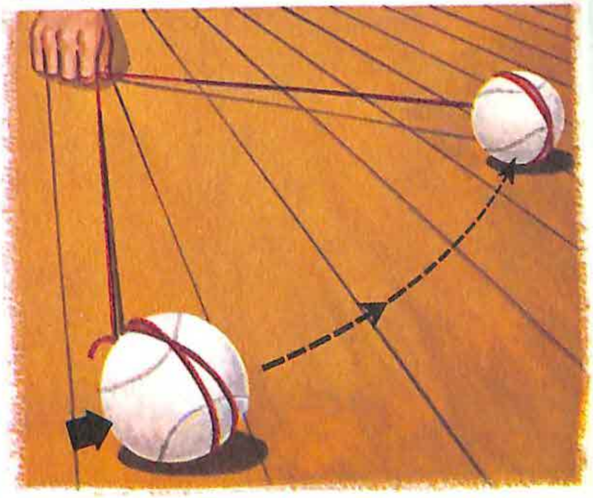
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You see, now, one reason why Isaac Newton is a very famous scientist. He dared to think that gravitation was more than just a pull on things on the Earth, pulling down apples and dogs and houses and people. He dared to think that gravitation reaches out beyond the Earth, to the Moon. It pulls between the planets and the Sun, and even between the stars. It pulls between all bodies traveling in space.

BEFORE YOU GO ON

Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. When you lift an object, you pull against the pull of the
   a. Earth
   b. Moon

2. The Moon would move away from the Earth if it were not for
   a. gravitation
   b. its round shape

3. A pull is needed to make a moving ball go in a
   a. straight line
   b. curve

4. The pull of gravitation acts
   a. only on objects on the Earth
   b. on all objects

USING WHAT YOU KNOW

1. A spaceship gets very near the Moon. What might happen to the spaceship?

2. A satellite is shot into space and goes into orbit around the Sun. What will be the shape of its orbit? Why?

ON YOUR OWN

Every now and then maps in the newspaper picture the orbit of a satellite. Check to see whether the orbit is an ellipse or not. Will there ever be an exception? Find one.

4. Comets and Some Other Space Travelers

Right now, as you read this, Halley's comet is heading toward the Sun, swinging in toward us from far out in the solar system, from beyond the orbit of the planet Neptune. As it curves around the Sun, we shall see it for a few weeks. In 1986, when Halley's comet is near the Earth, it will probably look something like this. 🟦 Then back out to the edge of the solar system the comet goes.

What is it that we see when we look at a comet? What is a comet made of?

A Ball of Ice

What are comets made of? This question has puzzled astronomers for many years. It still puzzles them. They are still not quite sure what comets are made of. They think, however, that a comet's *head,* the round, bright part, is a mixture of ice and bits of rock and dust. The ice has come from frozen gases. The head of a comet is like a huge, dirty snowball, someone has said.

The *tail* of a comet is a stream of very thin gases. The tail usually grows from the head as the comet gets nearer the Sun, and becomes longer and longer. However, it always

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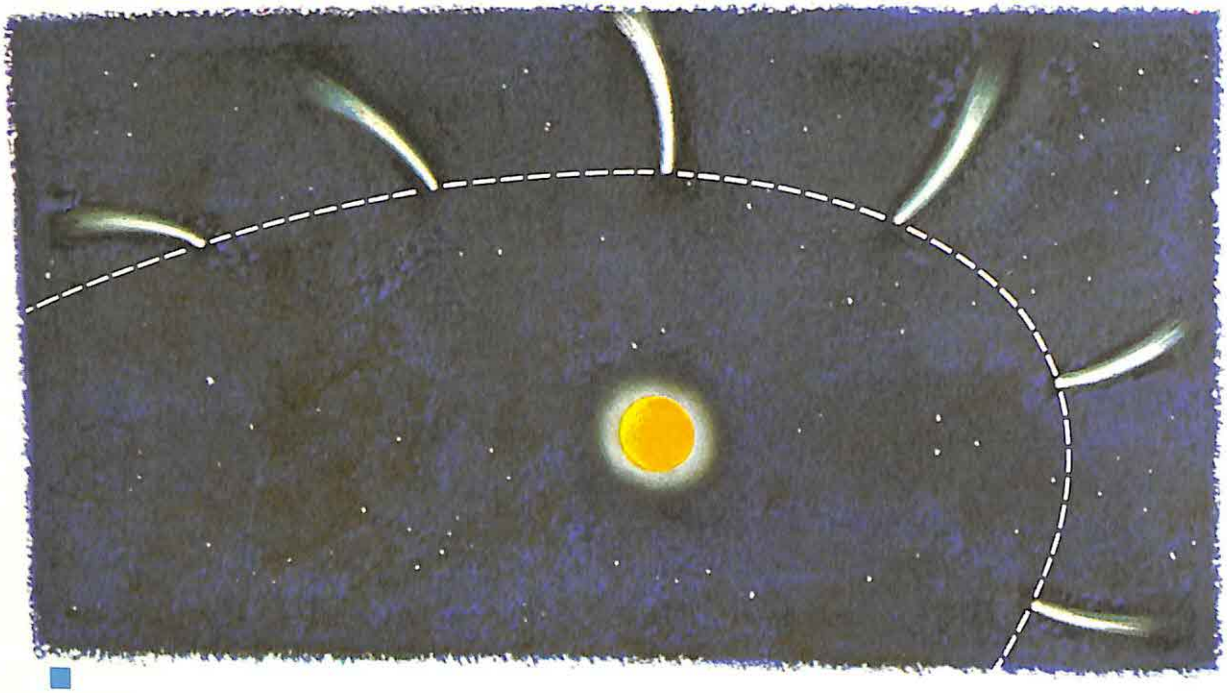

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streams away from the Sun, as the comet swings around the Sun.■ The comet then becomes brighter, too. A comet has no light of its own. It is lit by the Sun's light, like the Moon.

Astronomers suspect that millions of icy comets are swinging through space around the solar system. Every so often one of these balls of ice and rock swings in toward the Sun, and comes close to the Earth.

As a comet nears the Sun, some of its ice may turn to gas. In time, after several trips around the Sun, a comet may disappear. Halley's comet's last appearance, in 1910, was not as spectacular as the one before. It may be shrinking, but it still should make a good show in 1986.

When the ice of a comet turns to gas, what happens to the rocks and dust that were in the ice? These bits may become another kind of space traveler, a kind that we see much more often than comets. Some of these rocks may become "shooting stars," as people call them.

Not all scientists agree that "shooting stars" come from comets. Some scientists think the evidence is not clear. Investigations are being carried on now to get more evidence.

Since a "shooting star" is not a star at all, that is not a good name for it. It is called a **meteor** (MEE·tee·or). If you look for meteors, you may find them. Try the investigation on the opposite page.

AN INVESTIGATION into Meteors

Needed: a clear view of the night sky with no Moon, away from lights; two or three friends

Meteors may be seen at any time of night, but they do not appear regularly. Usually there are more meteors to be seen in the later hours of the night. Your friends and you might watch different parts of the sky, and call out when you see the flash of a "shooting star." ■

There are times when we see groups of meteors, as the Earth travels its orbit in space. At such times many meteors may be seen—so many that we speak of meteor "showers." Look for meteor showers around these dates:

Spring	Summer	Fall	Winter
April 29	July 29 August 12	October 22 November 17 December 12	January 3

Observe these things about meteors:

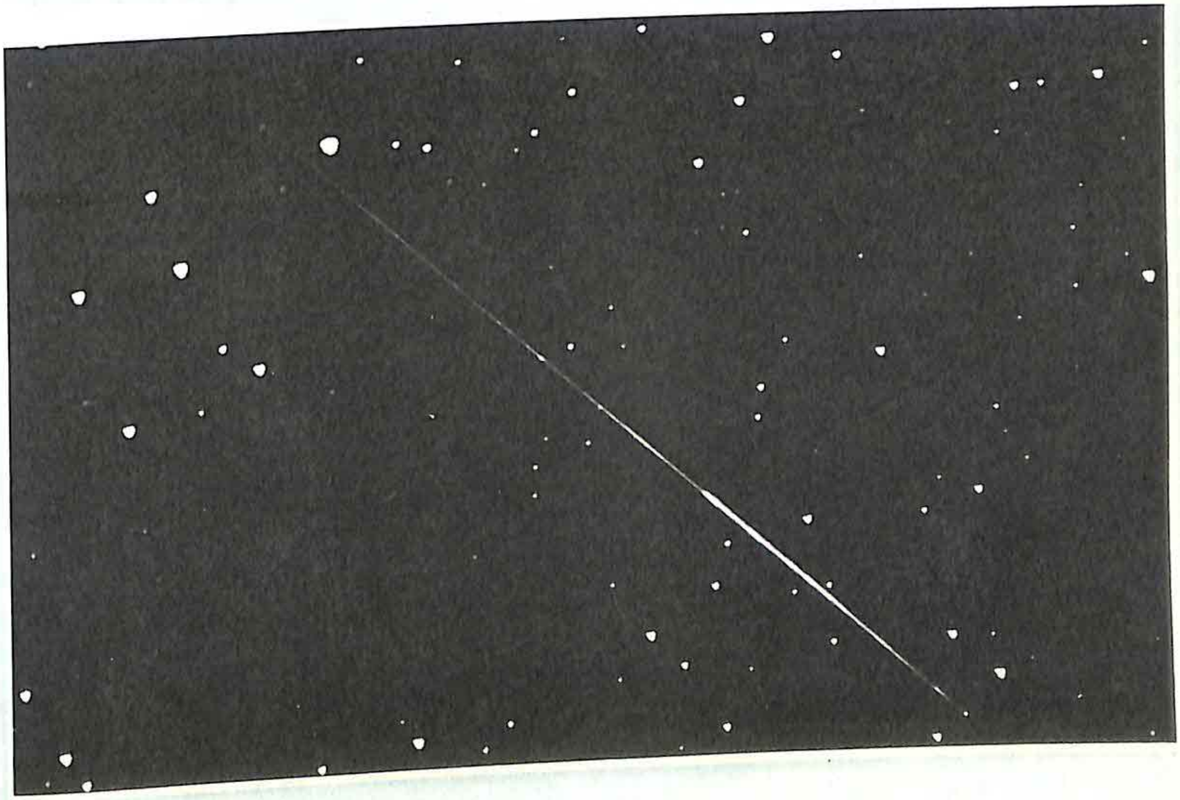
—Are they equally bright?

—Are they the same color?

—Do they come from the same direction?

—Do they last the same time?

■



A Streak of Light

When you have looked up into a night sky, you may have seen a sudden streak of light shooting across the sky for a short distance. 🟦 Just as suddenly as the streak appears, it vanishes. It is a meteor, a lump of rock speeding through space, which suddenly becomes white-hot and gives off light. Just as suddenly the light vanishes. What has happened?

Lumps of rock from the head of a shrinking comet may be of all sizes. Some may be pebbles, some huge boulders, some like dust. Imagine a large lump of rock speeding through space. The rock comes near the Earth. It is pulled toward the Earth by the Earth's gravitation. The lump of rock, speeding 20 to 40 miles each second, enters the Earth's **atmosphere** far above the Earth.

The atmosphere far above the Earth contains very little air. Even so, the air rubs against the speeding lump of rock. Press your hands together hard and rub them against each other. What do you feel as you rub? Heat. Rubbing makes **friction.** Friction makes heat.

The rubbing of the atmosphere against the speeding rock makes friction. The friction makes heat, enough heat to make the lump of rock white-

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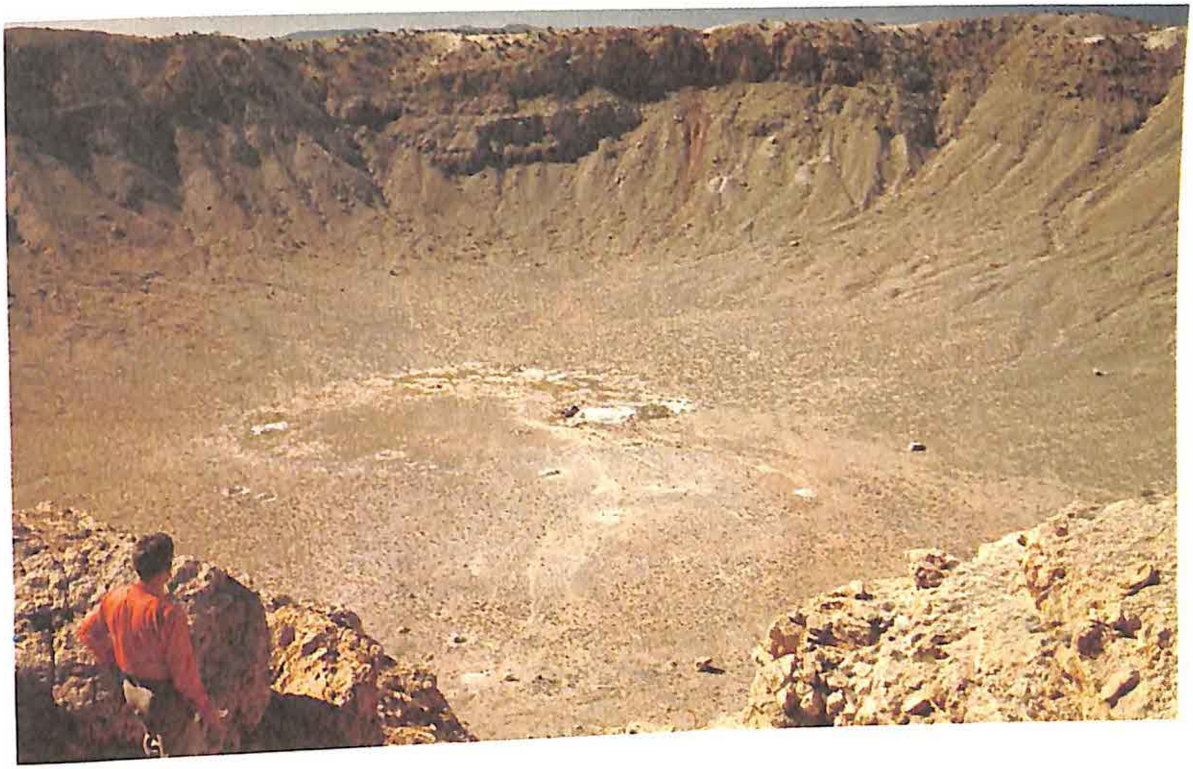

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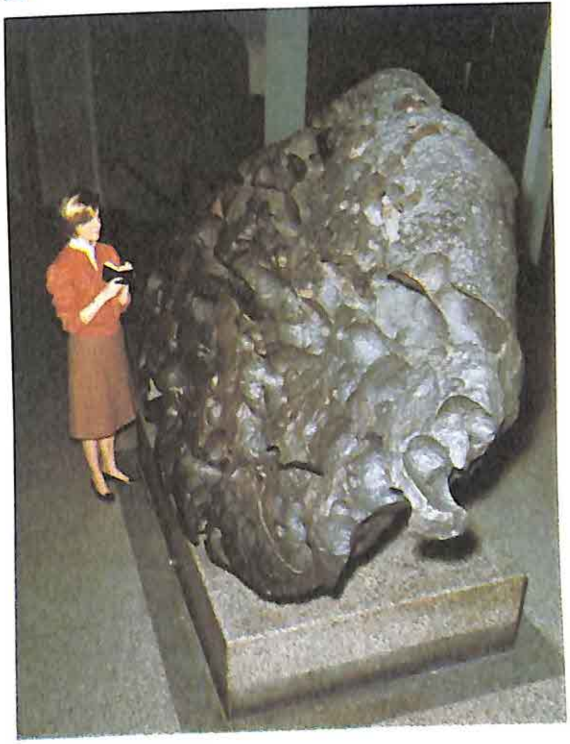


hot. This is the light we see when we see a meteor. The light goes out when the meteor has burned up.

Sometimes a meteor does not completely burn up. It plunges through the atmosphere and hits the Earth. It is then called a **meteorite.** When a meteorite crashes into the Earth, it may make a large hole, like this one. ● Here is a meteorite that was dug out of the hole it made in the Earth. ▲

Billions and billions of meteors are scattered throughout the space of the solar system. Some travel alone and some travel in swarms.

BEFORE YOU GO ON Study these statements and choose the correct responses. Your study will help fix in your mind the main concept of this section.

1. A mixture of ice, bits of rock, and dust is in a comet's
   a. tail b. head
2. A comet has
   a. no light of its own b. its own light
3. As it goes around the Sun, a comet may
   a. lose some of its substances
   b. gain some substances
4. Meteorites are found
   a. in space b. on the Earth
5. A meteor may come from
   a. the Sun b. a comet

USING WHAT YOU KNOW How could rocks in space be dangerous to space travelers?

5. When Scientists Predict

Halley's comet loops around the Sun about every 76 years. Scientists can predict the comet's coming and going. There are other comets, too, whose appearances can be predicted.

When will there be a full moon in the night sky again? The date can be predicted. The Moon moves around the Earth in an orbit. Scientists can predict where in that orbit the Moon will be at any time. The planets move in orbits around the Sun. Their positions can be predicted. When the Earth will speed through a cloud of rocks in space can even be predicted. Because scientists can predict, we know when to watch for meteor showers.

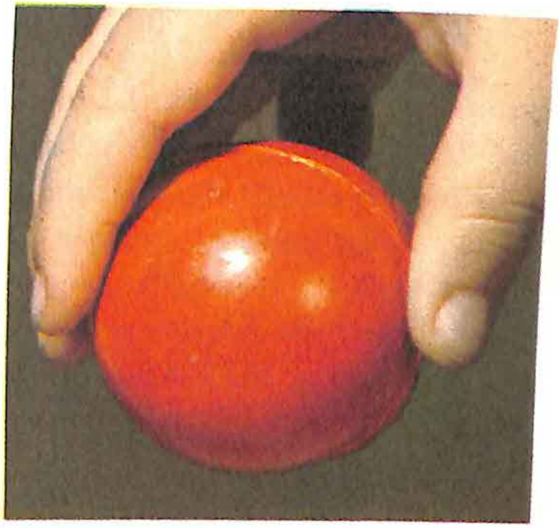
We are so used to such predictions that we think nothing of them. Let us, however, think about them. Why are scientists able to predict?

Knowing What Makes It Work

Ask a young child what happens if he lets go of a ball in his hand. ■ He will tell you that the ball will fall, of course. (He may think that you are rather stupid to ask, too.) He makes a prediction about the ball. He knows that the ball has always behaved that way in the past. He expects that it will go on behaving that way. He predicts that it will.

This is one way of predicting, certainly. You have, however, been studying a better way in this unit.

Why are astronomers able to predict that Halley's comet will appear again in 1986? Not just because that comet has appeared again about every 76 years for at least 2,000 years that we know of. Scientists predict the return of that comet because they understand what makes it return.



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What makes Halley's comet come back? The shape of its orbit, which is an ellipse. What shapes the orbit of the comet? The pull of gravitation. There is not any sign that the pull of gravitation is going to stop working. Gravitation shapes the path of the comet. So long as this is so, that path may be predicted. ●

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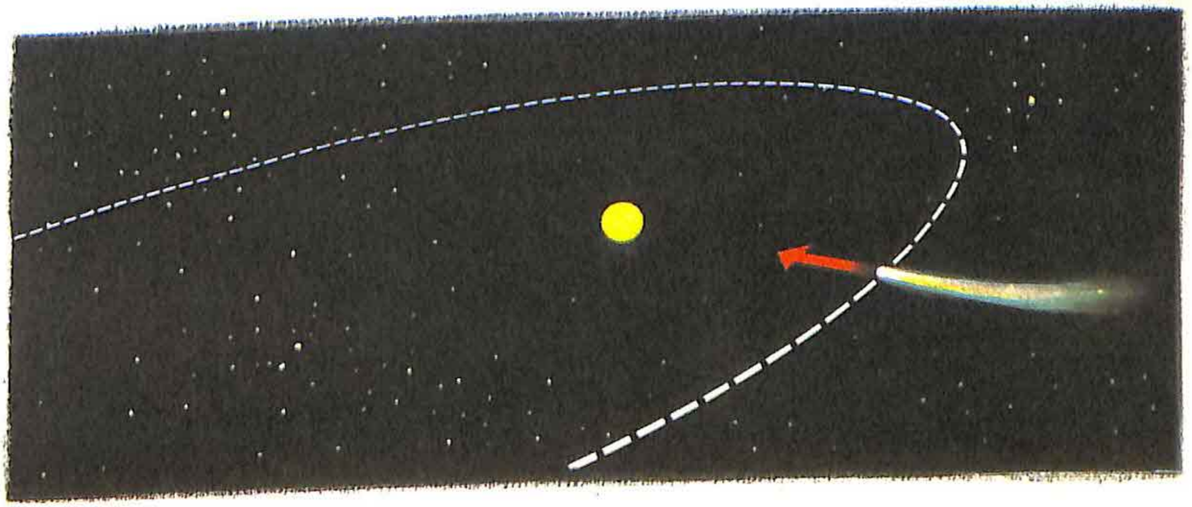


Gravitation shapes the path of the Moon around the Earth. Gravitation shapes the path of the Earth around the Sun. Gravitation shapes the paths of the planets around the Sun, and of the stars in the universe. So far as we know, gravitation is not changing. So we do not expect changes in the orbits of the Moon, the Earth, and the planets. Thus their orbits can be predicted. We understand something about what makes them work.

If *you* were asked what would happen to a ball when you let go of it, you would give the same answer as a young child. You would make the same prediction. Your prediction, however, would be more scientific. You know something about what makes the ball work that way.

The Tardy Comet

Halley's comet turns up about every 76 years, on the average. Yet Halley's comet does not always appear again in just 76 years. Sometimes it appears in as few as $73\frac{1}{2}$ years, sometimes in as many as $78\frac{1}{2}$ years. Halley's comet probably will appear again more than 76 years from its appearance in 1910.

Sometimes Halley's comet passes near the planet Jupiter. ■ Jupiter, like every other body, has a pull of gravitation. When Halley's comet comes close enough to Jupiter, the comet may be held back a little because of this gravitation. As a result, the comet may take a little longer to reach the Earth. Or sometimes the comet may be pulled forward a little, and reach the Earth a little sooner.

Even so, scientists can calculate when the orbit of the comet will pass close to Jupiter. Gravitation is at work. They can calculate what effect Jupiter's pull will have. They can still predict the arrival of Halley's comet accurately.

There is more to making predictions than this, of course. However, science is a way of finding out how the world works. Scientists can make predictions when they understand how a thing works.

So can you.

■

BEFORE YOU GO ON

1. Why can scientists predict the positions of the Moon and Earth?

2. Why can scientists predict the time of the return of Halley's comet?

3. How can scientists predict when Halley's comet will be late?

ON YOUR OWN

List some things that you can predict because you know how they work. Here are two predictions to start with: a ball will fall to the ground; a saucer of water will evaporate.

6. The Main Concept: Regular Change

An astronaut may travel in orbit around the Earth in about 88 minutes.

The Moon travels in orbit around the Earth in about 28 days.

The Earth travels in orbit around the Sun in about 365 days.

Halley's comet travels its orbit, around the Sun and beyond Neptune and back, in about 76 years.

Earth, Moon, and comet change their positions every moment. They are always moving. They are never still. And yet, we know that these movements can be foretold. Scientists are able to predict where these restless bodies will be in the future. Scientists can predict because they understand the forces that are at work on these bodies. They know what forces shape the orbits of the Moon and the Earth. They know the forces that shape the long ellipse of Halley's comet.

They know that while comets, planets, Earth, and Moon are always changing position, the force of gravitation does not change. That is, the effect of gravitation on comets, planets, Earth, Moon, or any body, does not change. The effect of gravitation remains unchanged.

So in the midst of movement and change, in the midst of what seems at first disorder, we have been able to find a hidden order. We have found that change can be regular.

Fixing the Main Concepts

TESTING YOURSELF Study the statements below and choose the correct responses. Your study will help fix in your mind the main concepts of this unit.

1. The Earth's orbit
   a. cannot be predicted b. can be predicted

2. The orbit of a space satellite
   a. can be predicted b. cannot be predicted

3. Halley's comet has
   a. a predictable orbit
   b. an orbit which is not predictable

4. Meteors
   a. always hit the Earth
   b. do not always hit the Earth

5. The orbit of a planet is
   a. a circle b. an ellipse

6. An orbit is shaped by
   a. the pull of gravitation
   b. the prediction of scientists

7. Halley made his discovery
   a. without using the work of other scientists
   b. by using the work of other scientists

8. Scientists think that a comet's head may partly be made of
   a. water b. ice

9. Newton told his friend Halley that the orbit of a comet was
   a. impossible to calculate b. an ellipse

10. When Halley's comet gets near the planet Jupiter, it is attracted to Jupiter by the force of

a. magnetism b. gravitation

FOR YOUR READING

1. *Off Into Space! Science for Young Space Travelers,* by Margaret O. Hyde, published by McGraw-Hill, New York, 1959. For the researcher into space, a good deal of information is given about the solar system, gravitation, and the concepts underlying rocket travel.

2. *Shooting Stars,* by Herbert S. Zim, published by William Morrow and Company, New York, 1958. Here is a good book about meteors.

3. *Worlds in the Sky,* by Carroll L. Fenton and Mildred A. Fenton, published by the John Day Company, New York, 1950. And here is a good introduction to astronomy.

GOING FURTHER

You were born into the Space Age. Perhaps you will discover a new comet. It has been done by young people not much older than you.

Why not investigate how comets have been discovered?

A New View of Change

The mountains look as if they could stand forever, unchanging. Yet we know that they cannot, for they are changing. Heat and cold, water and wind are slowly breaking them down.

A little water runs into a crack in a rock. ■ The water freezes in the crack. As the water freezes, it expands. The crack widens. During the day, the heat of the Sun makes the rock expand. In the cold of the night, the rock contracts. Cracks appear, and widen. Wind and rain wear away the rock surface and carry off bits of rock.

Slowly, slowly, the mountains are being broken down. Streams and rivers pick up the tiny bits and carry them away. When the running water slows down, it drops the bits in valleys and lakes and oceans. And so, slowly, the land is built up again. Along the seacoasts the rivers deposit millions upon millions of tons of this material on the sea bottom. As this great weight presses down in one place on the crust of the Earth, the crust may rise slowly in another place. For under the Earth's crust is a doughy layer of hot rock that can

■

flow under great pressure. This is one way in which new mountains may be made. So, over millions of years, mountains are being worn down in one place, and raised up in another place.

The concept is plain: the Earth is changing.

Living Things Change

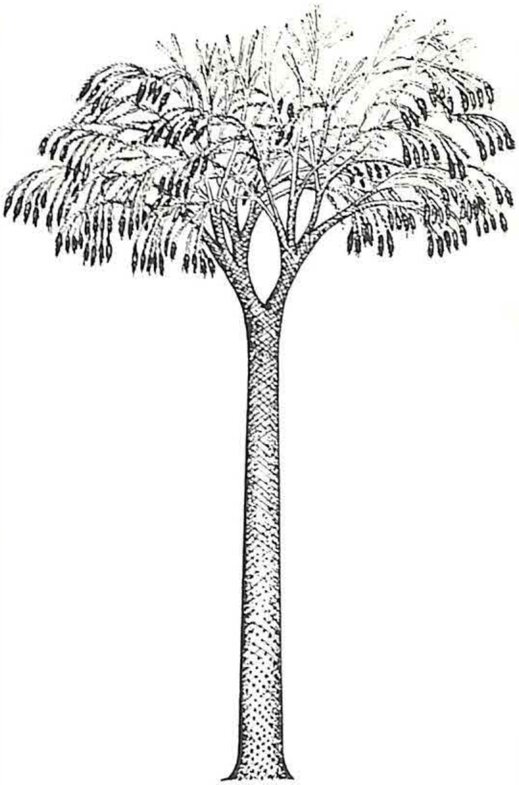
Nor is the Earth the only thing that is changing.

Here is a plant that once grew on the Earth.● It no longer grows anywhere on the Earth. It has disappeared, and other different kinds of plants have taken its place.

You recall that many kinds of animals once lived on the Earth that are no longer found. These ancient plants and animals gave rise to other plants and animals which are alive now. Slowly, and little by little, living things on the Earth have changed. Slowly, plants and animals on the Earth are changing now.

The concept is plain: living things are changing.

The Earth changes its place in space. It is rotating. It is revolving in an orbit around a star, the Sun, along with other planets. The group of stars to which the Sun belongs is moving, as well, through space.



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Changes You Can See

Look at a burning log, a melting piece of ice, an evaporating puddle of water. All around you, matter changes. Rub your hands together. Your hands get warm. You have changed the energy of your moving hands into heat energy. Energy changes. Look at a planted seed. It grows, and changes. A young puppy grows and changes. Salmon, ducks, geraniums, flies change.

Look at a picture of yourself taken only a year ago. You have changed. You are changing now. Life changes. The Earth changes. The universe changes.

Understanding Change

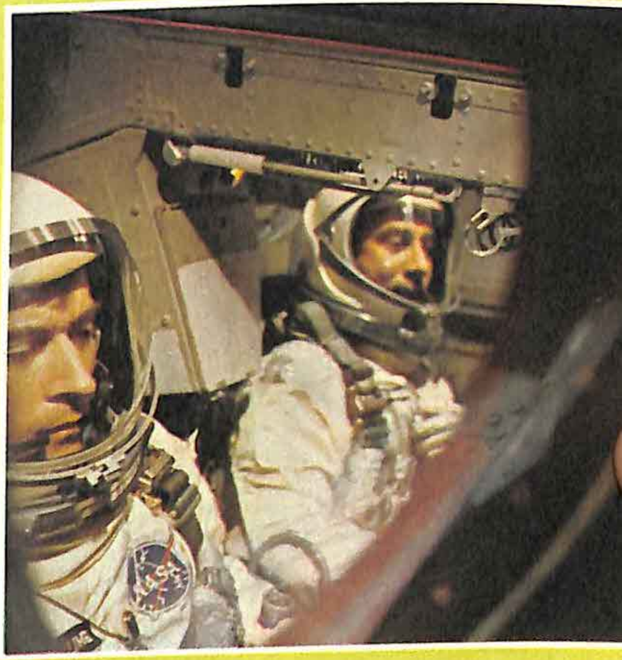
Changes are all around us. We study these changes. We learn more and more about them. As we do this, something happens. We begin to understand why changes happen. And we can predict changes. We can say what will happen, before it happens.

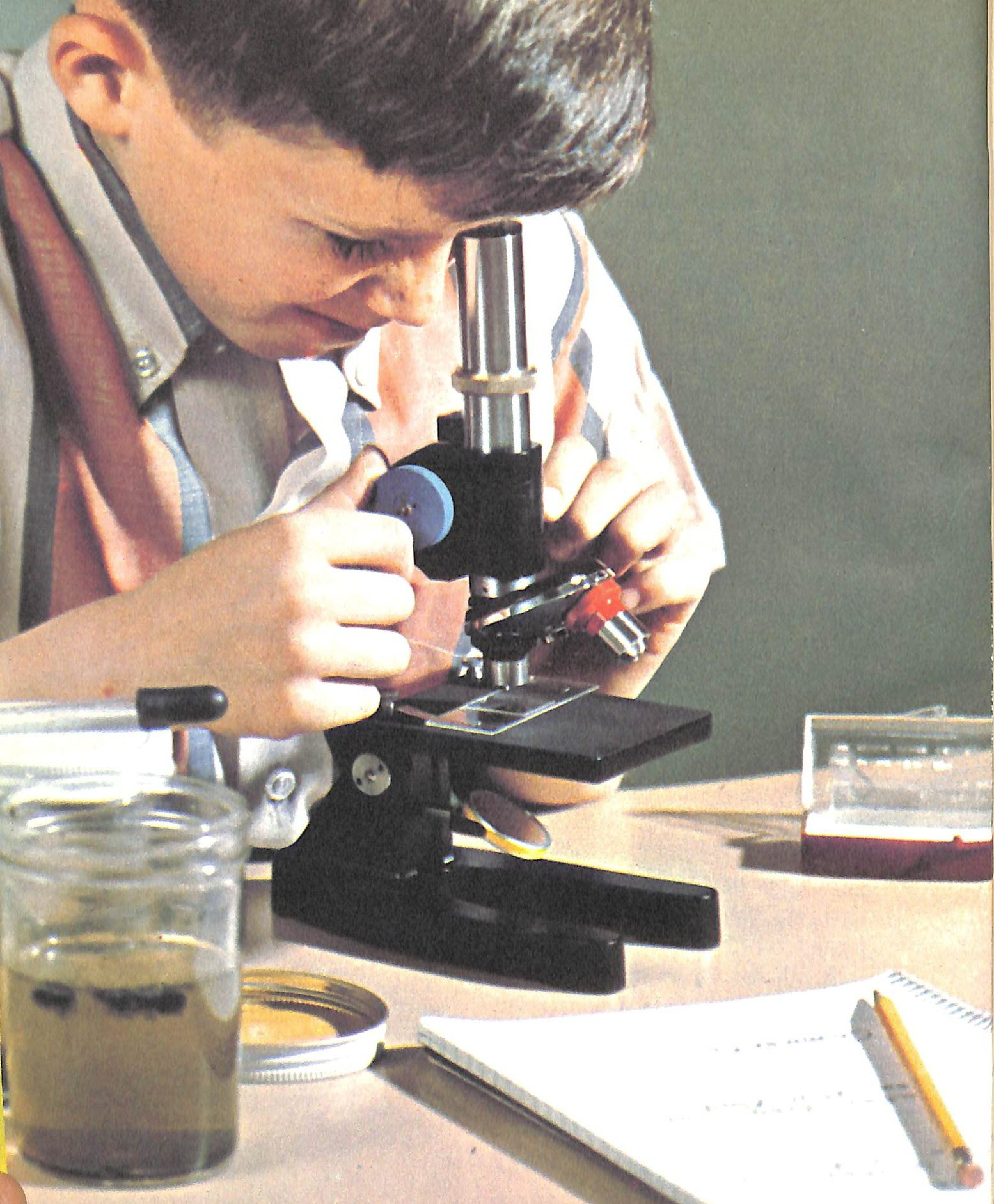
We can predict where the Earth will be in its orbit ten years from today. We can predict what will happen to planted seeds. We can predict the arrival of a comet in the night sky. ■ We can predict some of the changes that will happen to the surface of the Earth. We can even predict some of the changes that will happen to living things.

We still have a great deal—an enormous amount—to find out and learn. But with what knowledge we have, we can begin to predict a few of the changes that are always going on around us and happening to us. We can begin to predict because we are beginning to understand what makes the changes happen. Thus we can learn to live in the midst of change.

Remember, too, that man is more than a living thing to which changes happen. A seed cannot plan to make changes. It cannot plan to alter the world it lives in, if that world is not a good one for it. A seed cannot do anything to bring the water it needs to where it lies, for instance. A seed cannot make deliberate changes in its environment. But man can make changes. Man can plan to change the changing world in which he lives. Man can use his mind to understand the changing world, and use the knowledge he obtains to make the changing world a better place to live in.

To do this, man needs not just knowledge and understanding, but wisdom. For the changes that man plans now shape the future for man to come. ●





ON YOUR OWN

PROBING WITH A MICROSCOPE

A drop of pond water is a world in itself. It is a world of such strange animals and plants that you will find it hard to leave once you enter it.

How can you enter this world? How can you explore it and probe it? You can use a microscope and simple equipment, such as jars, and medicine droppers, and slides.

First, however, you must catch some of these living things. Then you must feed them and shelter them, so that you can observe them as you want to. When you stop to think that these living things are so small that you can't see them with your eye alone, catching and feeding and housing them may sound difficult. It isn't hard at all.

Collecting Invisible Living Things

Plan a field trip with some friends. Take along five jars with caps, about this size. ■ Look for a small pond

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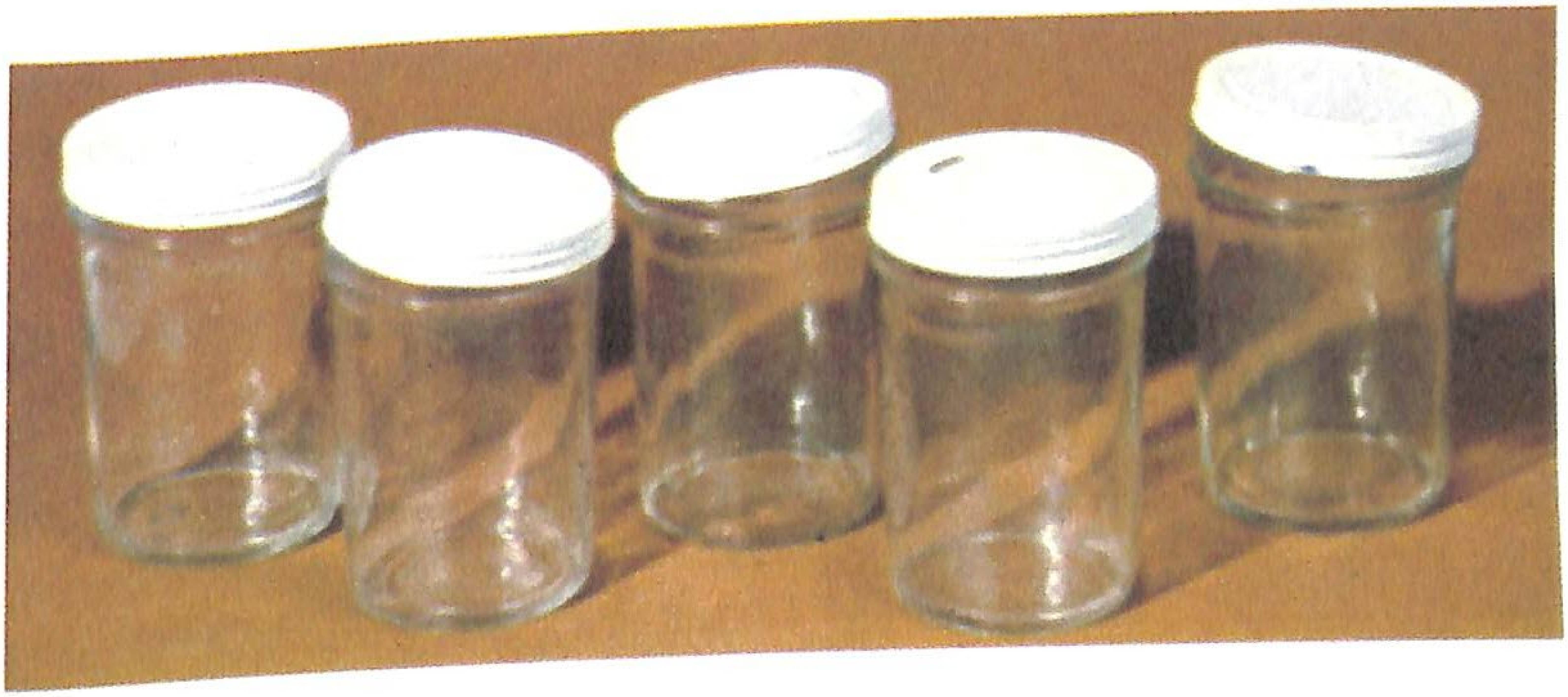

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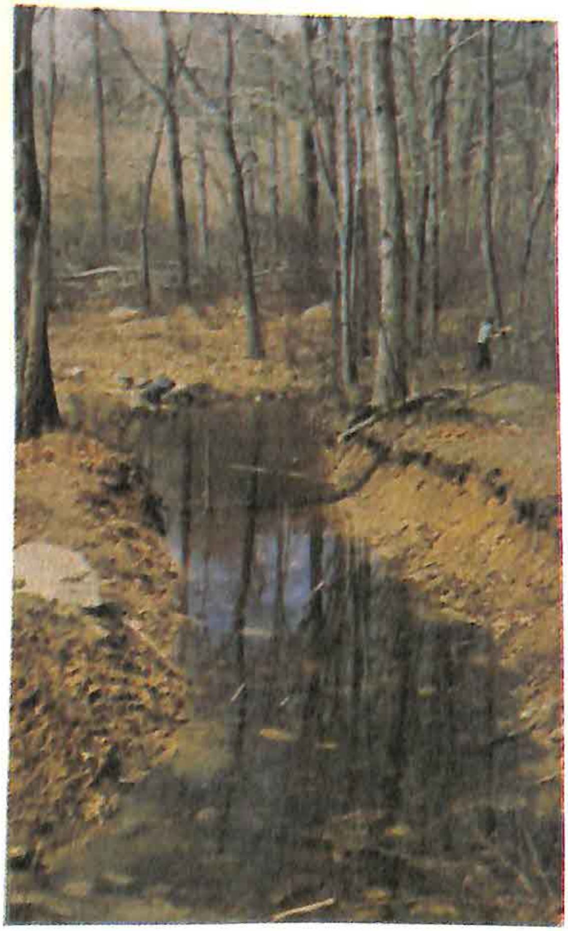
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or a stream that flows slowly.■ Even a ditch with water in it, like this may do.● Look for a place where water plants are growing.

Fill each jar about three-quarters full of the water from the pond. If you can, get a little mud or soil from the side or bottom in as well.▲ If some plants that grow under water are within reach, add a bit of plant to each jar.◆ It is the pond water that you want, though. The mud and the plants are not so important, so don't reach too far for them. (Falling in isn't a good way to collect pond life.) Cap the jars tightly.

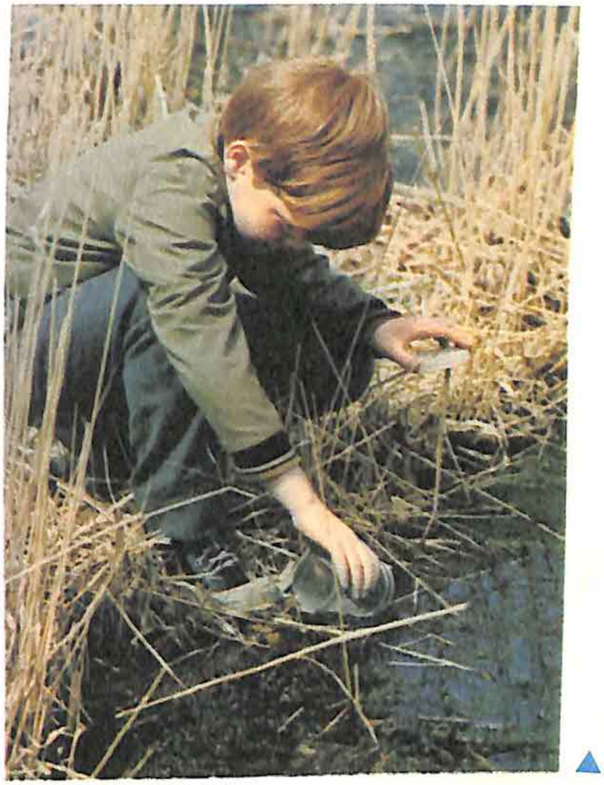
Bring the jars of water home, or back to the classroom, and let them stand for twenty-four hours. Let them stand in a cool place—avoid heat if you can. And don't put the jars in bright sunlight. Medium light, not very bright, is best. This will give things a chance to settle down.

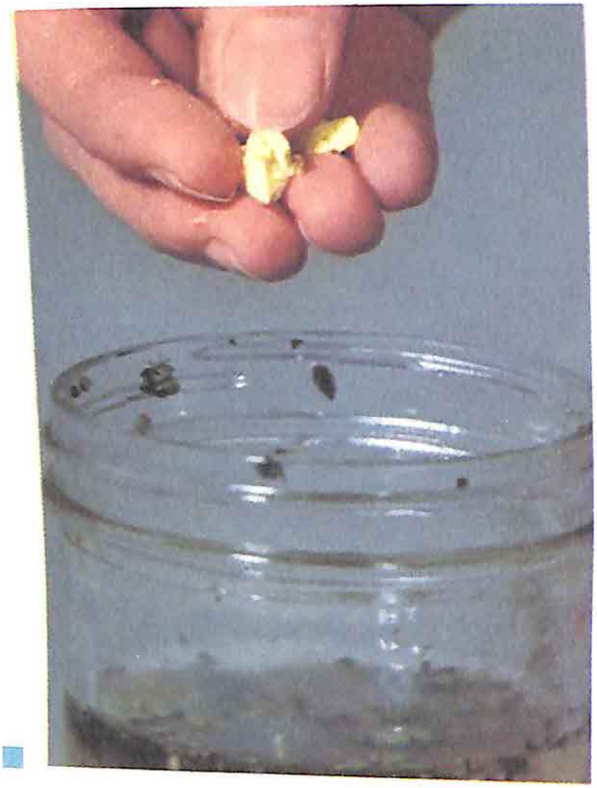
Don't keep the jars tightly capped. Unscrew the caps and set them on top of the jars, loosely. In this way they can let air in, yet keep dust and dirt out of the water.

Growing Invisible Living Things

The pond water in the jars contains tiny living things. It contains tiny animals, called protozoans, that are made up of only one cell. It contains tiny green plants called algae. If you looked at a drop of this water through a microscope, however, you might not find one of these protozoans or algae. You could examine drop after drop of water until a protozoan or an alga appeared, but you might have to examine quite a lot of drops. Fortunately there is a better way. It is to get the protozoans and the algae to reproduce. If conditions are right, they will reproduce in large numbers. Then there will be so many of them that almost any drop of the water will have protozoans and algae in it.

If these living things are to grow and to make more of their kind, they must have food, of course. Here are some good ways to feed them.





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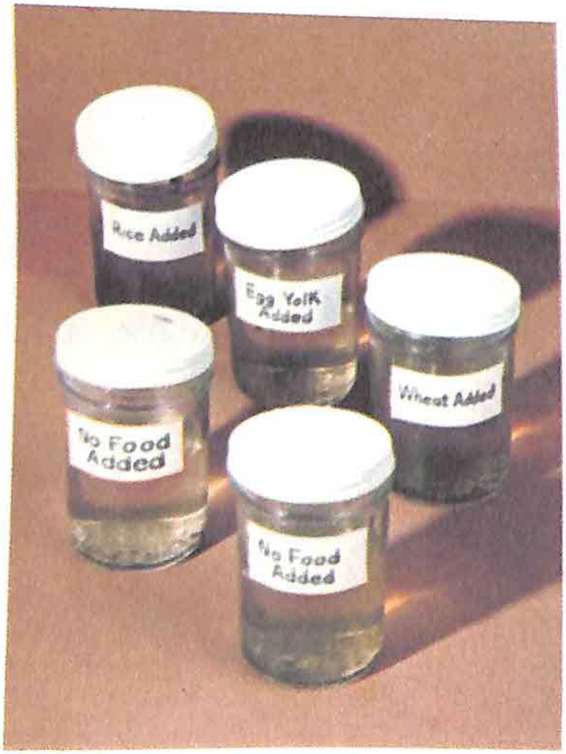

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Boil an egg until it is hard—about twenty minutes. Take a piece of the yolk about the size of a pea. Crumble the piece of yolk between your fingers, letting the crumbs drop into one of your jars of pond water. Label that jar "Egg yolk." ■

Get a little rice. Drop about five grains of the rice into another jar. Label it "Rice."

Put five grains of wheat into one more jar. Label it so that you know what food is being used in this jar.

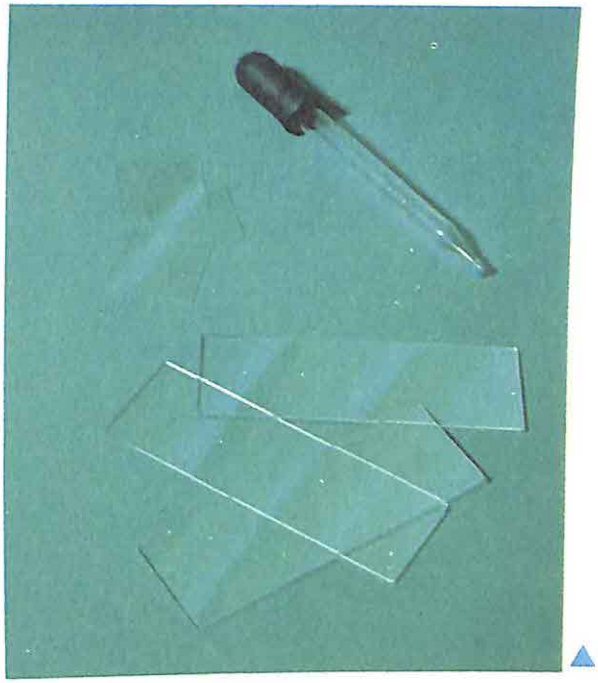
Put no food into the two jars that are left. Let those jars stay as they were when you collected them, so far as food goes. ●

Return all five jars to the place where they are not too warm and do not get too much light during the day. Observe them carefully, day by day. Within a week or two (if your pond water had any protozoans in it to begin with) the jars will swarm with tiny specks that you can see moving about. These specks will be protozoans and other animals.

Which jars do you suppose will have the most tiny animals? Which kind of food will produce the most protozoans—egg yolk, rice, or wheat?

The egg yolk and the grains of rice and wheat are not food for the protozoans, by the way. The egg yolk, the rice, and the wheat furnish food for bacteria in the water. Bacteria are very tiny plants, each made up of a single cell. (They are not green, even though they are plants.) As the bacteria feed on the egg yolk, it decays —so these bacteria are called decay bacteria. Some decay bacteria are illustrated on page 162. The decay bacteria and other small protozoans are food for large protozoans.

Now, with your own supply of growing and reproducing protozoans and algae, you can study the kinds of living things in a drop of water.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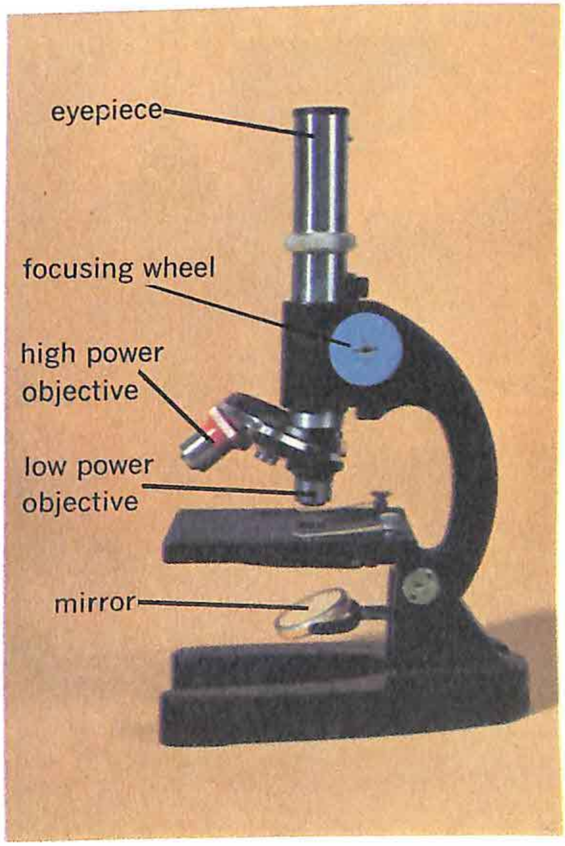
Using a Microscope

Here are some things you need, as well as a microscope, for observing life in a drop of water: slides, cover slips, a medicine dropper.▲

Let's examine a microscope, first.◆ The upper lens, the one you look through, is called the eyepiece. The lower lenses are called objectives. There is a number on the top of the eyepiece of this microscope: "10×." Each of the objective lenses is marked with a number also. One lens is marked "10" and the other lens is marked "40." These numbers indicate the magnifying power of these lenses. The eyepiece magnifies ten times. The objective lenses magnify ten times



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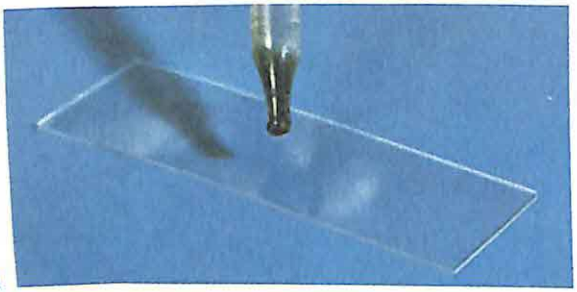

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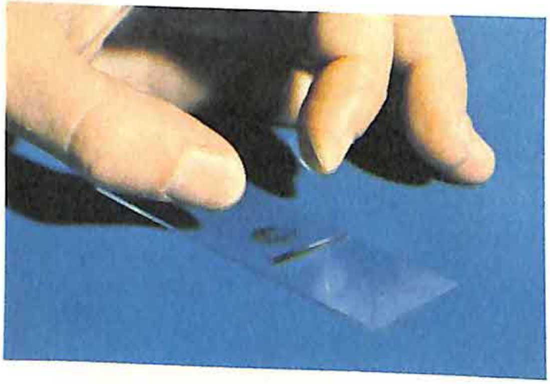

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and forty times. How much does this microscope magnify? Multiply the number on the eyepiece by the number on the objective being used. For the low-power objective, marked 10, this is 10 × 10, or 100. Using low power, the microscope magnifies 100 times. An object placed under the low power lens looks 100 times as big as it actually is. Multiply the number on the high power objective by the number on the eyepiece: 10 × 40 is 400. The high-power objective magnifies 400 times.

The wheel at the side of the microscope is for focusing. When the wheel is turned, the distance between the objective lens and the object being observed is changed. The mirror is for reflecting light onto the object being examined.

Perhaps the easiest way to begin using the microscope is by looking at one of your own hairs. Follow these steps.

—Take up a little clean water in the medicine dropper. Put a small drop on a slide. ■

—Put a piece or two of hair from your head in the drop. ●

—Touch a cover slip to the edge of the drop of water. ▲

—Gently lower the cover slip onto the drop. It will flatten the hairs a little, making them easier to examine, and prevent the drop from evaporating quickly. ◆

Now the hairs are mounted on a slide and ready to be examined.

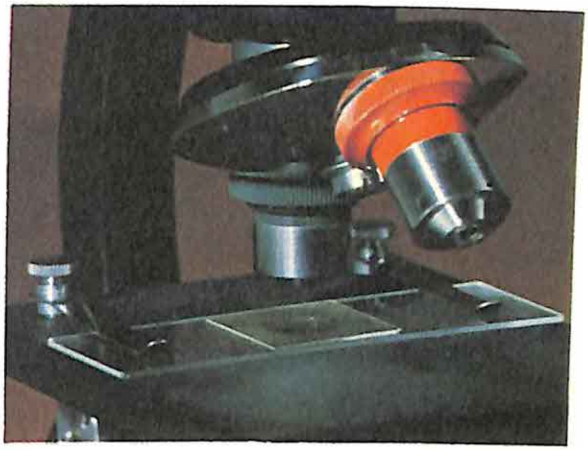
—Swing the low-power lens into place under the eyepiece. It will click into place.

—Put your eye to the eyepiece. Turn the mirror toward a window or a light so that light is reflected into the microscope. You will see a bright circle of light in the eyepiece.

—Take your eye from the eyepiece. Put the slide under the clips on the microscope stage so that it is held firmly. Place the slide so that the hair is in the light from the mirror.

—Turn the focusing wheel so that the low-power objective moves slowly down toward the slide. Stop when you see the lens is about an eighth of an inch from the slide.★

—Now put your eye to the eyepiece and turn the focusing wheel the other way so that the lens moves up, away from the slide. *Be sure to turn the wheel so that the lens moves away from the slide.* If you turn the wheel the wrong way, you may run the objective into the slide, break the cover slip and the slide—and scratch the lens. Turn the wheel until the hair is in focus, as sharp and clear as possible.



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—Try moving the slide around with your fingers carefully, while looking through the eyepiece, so that other parts of the drop can be seen. ◆

—To look at the hair through the high-power objective, swing the high-power objective around until it clicks into place under the eyepiece. It will be very nearly in focus. Move the focusing wheel very carefully, for the high-power objective is very close to the cover slip and slide!

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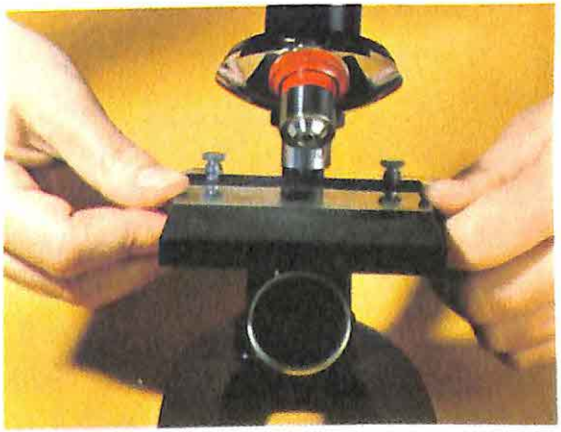

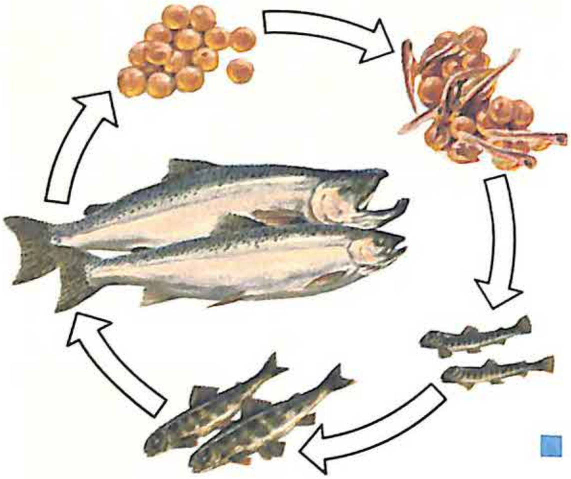

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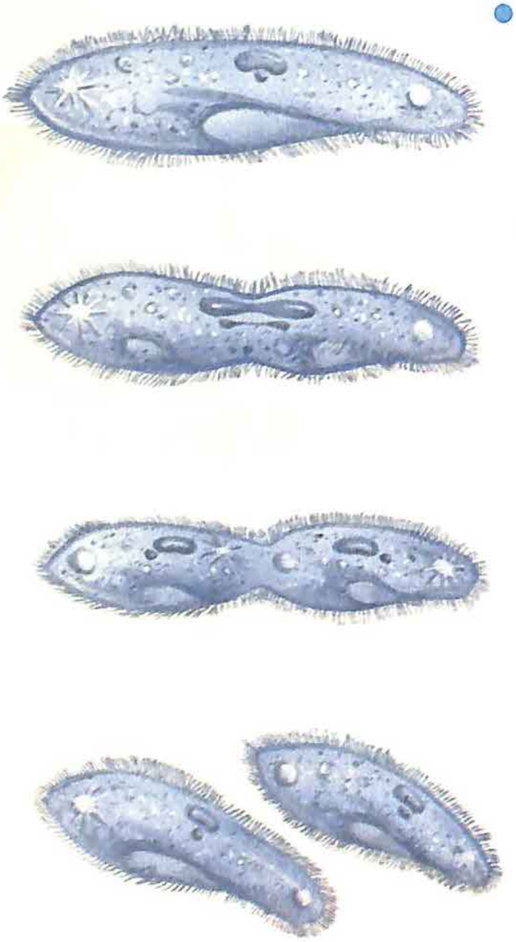

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and plants that live in a drop of water, you may want to know more about how they live. Try some of the investigations that follow.

INVESTIGATIONS

A Protozoan's Life Cycle

You know that many events take place in what we call a cycle—a certain order that is repeated over and over.

The salmon, for example, have a life cycle that begins with eggs. The eggs grow (some of them) to be young salmon. The young salmon (some of them) grow to be adults. The adult salmon produce eggs—and the life cycle starts over. ■

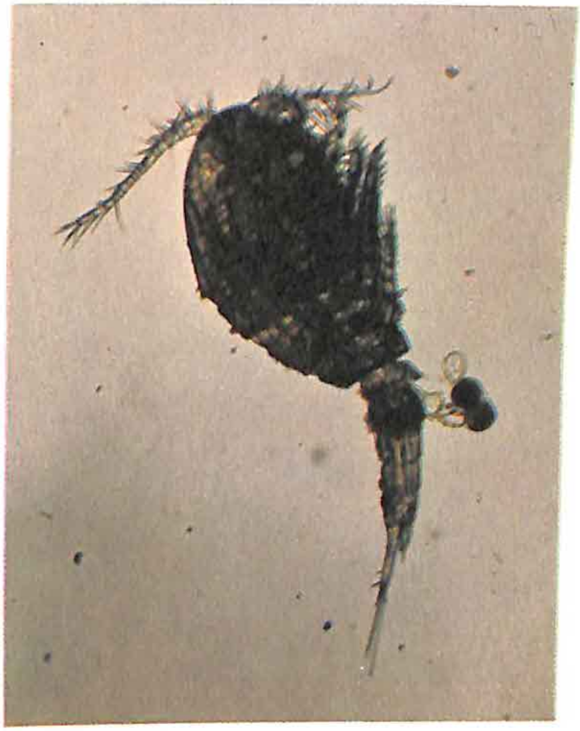
Every living thing has a life cycle. What is the life cycle of a protozoan like, then?

To investigate this, a good thriving collection of protozoans is needed, a *culture* of protozoans, as scientists say. Such a culture is a kind of tiny pond, isn't it? It is a kind of pond you can observe closely, and when you wish.

Use the microscope to find in a culture some animals that seem to be dividing in two, like this one. ● When you find one or more dividing protozoans on a slide, seal the edges of the cover slip to the slide with Vaseline. This will prevent the drop of water from evaporating. Drying out will kill the protozoans quickly. By sealing the cover slip you can observe a dividing animal for some time. Try to observe a dividing animal (which is called a parent) until it separates into two animals (called daughters). Are the daughters like the parent? Are they about the same size as the parent?

Most of the tiny animals in your cultures reproduce by dividing in two. This dividing in two is known as fission. But some of the animals in the culture reproduce in other ways than by fission. See if you can observe how water fleas reproduce, for example. ▲

There are many different animals and plants in your cultures. In some ways you could compare the population in one of your culture jars with the population of plants and animals in a forest. For instance, the population of animals in a forest depends on plants for food. (Even the animals that eat other animals depend on plants, in the end.) Your population of protozoans depends on plants, too. The smaller protozoans feed on bacteria. Bacteria are plants. What some of the larger protozoans feed on is suggested here. ◆



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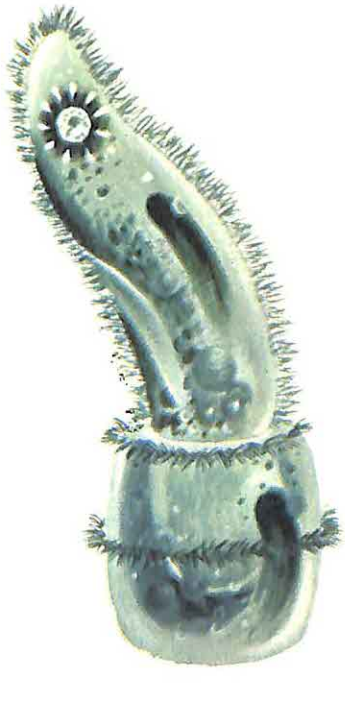

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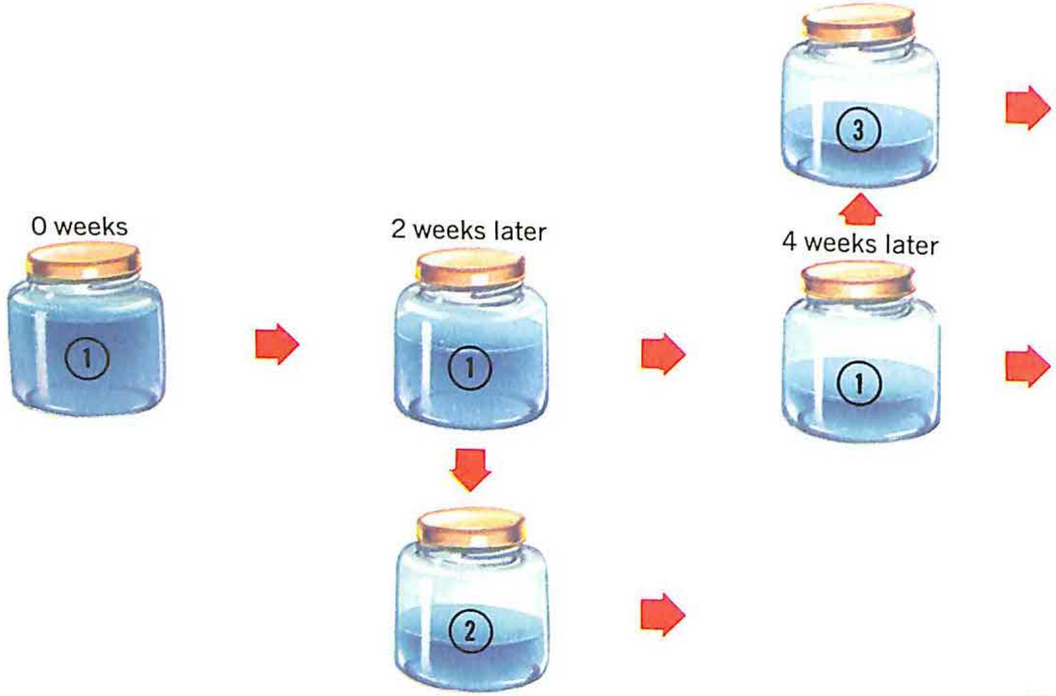

The animals in a forest depend on light and air. So do the protozoans in your cultures.

Sometimes in a forest one kind of animal will reproduce in extraordinary numbers. Sometimes it may be the rabbits, sometimes the deer. On the whole, though, the population in a forest stays in a kind of balance. You might have a hard time observing this in a forest, but it is not hard to study the population in your cultures.

Does the population of protozoans in your cultures balance? Does it go through any changes? Every day examine drops of a culture from different parts of a jar. Take water carefully from the sides, bottom, and top of the jar with the dropper. Try not to disturb the culture while doing this.

Keep a record every day of your observations. See what answers you can find to questions like these:

—Which animals in the culture seem to be greatest in number? How long do they remain so?

—Is there any change in the kind of animal that is greatest in number as the culture gets older?

—After about four weeks, how does the population of the culture differ from the population at the beginning?

Of course, whatever you observe will be happening in only one culture.

Will the same sort of thing happen to the animals in another culture? What is your guess? To find out, start some more cultures.

Starting New Cultures

Collect a jar of pond water again, about three-fourths full. Crumble a little hard-boiled egg yolk into it, as you did before. Label it "Culture 1." From this culture you can start two more cultures that will give you a clearer idea of the growth cycles. Start Culture 2 from Culture 1 after Culture 1 has been growing for about two weeks. Start Culture 3 from Culture 1 after Culture 1 has been growing for about a month. ■

To start Cultures 2 and 3 you must of course prepare the environment in which the animals and plants can live. Put water into a jar until it is about half full. Water from the tap will do. Crumble a pea-size bit of hard-boiled egg yolk into the jar. Let the jar stand for three days. During this time bacteria will feed on the egg yolk and develop. You should do this, then, three days before it is time to start a new culture from Culture 1.

About two weeks after Culture 1 was started, stir the culture thoroughly. Then pour about one third of Culture 1 into the new jar, where it can develop by itself. Label the new jar "Culture 2." ●

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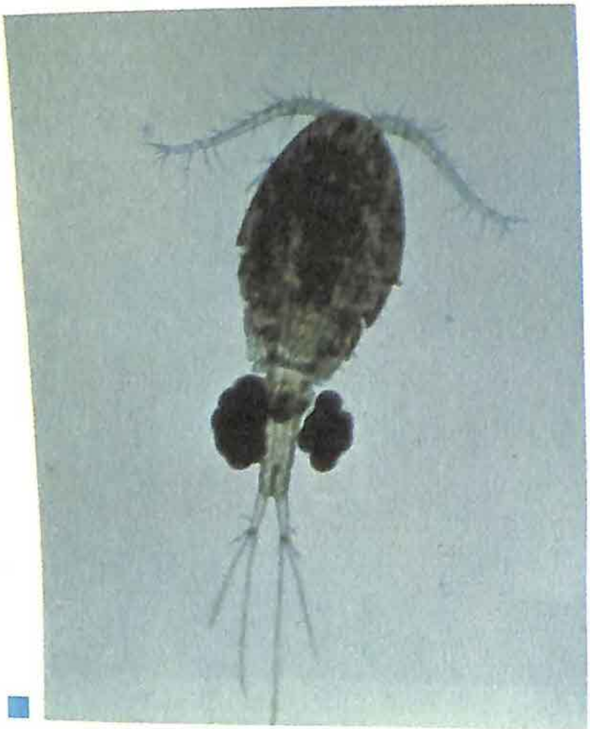
Two weeks later, stir Culture 1 thoroughly again and pour about one half of it into a prepared new jar. Label this "Culture 3."

You can observe how each culture develops by examining drops of water from each one under the microscope.

What differences can you observe between the populations of the three cultures?

Do the populations in the cultures go through the same sort of cycle, no matter when they were started? Or do the different cultures have different cycles?



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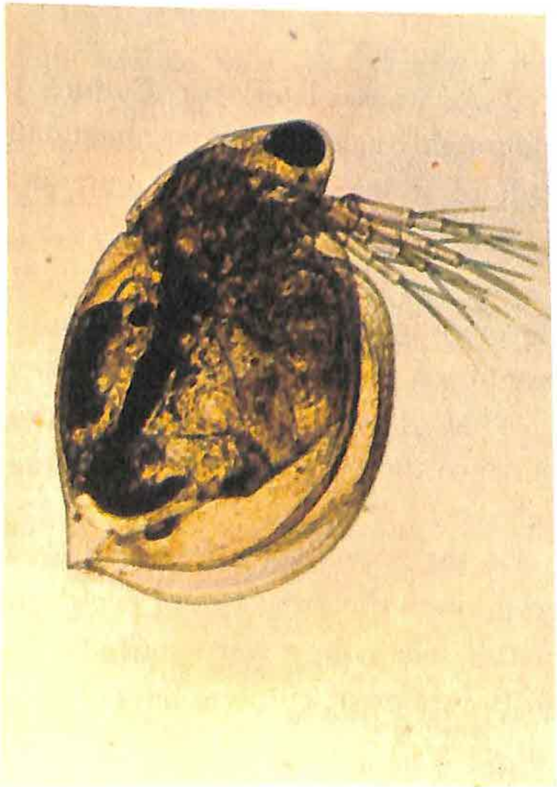

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As you observe what happens in the three cultures, you will probably think of some interesting questions of your own. Why not investigate them?

More Investigations to Try

Some of these animals in your pond cultures reproduce by dividing in two, by fission, that is. Others reproduce by means of eggs.

If your pond water culture has water fleas in it, try to catch some in drops of water, and examine them under the microscope. You may be able to see the eggs. ■

See if you can observe how long it takes a Daphnia or a Cyclops to reproduce. One way to do this is to take a fresh supply of water swarming with bacteria that you have prepared as food for your pond culture. Put some in a very small bottle. Capture, in a drop of water, a Cyclops or a Daphnia which is carrying eggs. Add this drop to the water in the small bottle. How long is it before young Daphnia or Cyclops appear in the water? ●

You may have to do this several times to get it to work properly. All eggs do not develop.

How do the microscopic animals in your pond water culture behave? You can observe this, too. Try this investigation. Pour a thick culture of Euglena into a clean test tube until the tube is about three-quarters full. Stand the tube in a rack or a glass tumbler.

Don't disturb the tube for about ten minutes. At the end of that time the tube may look something like this. ▲

What has happened in this tube? Most of the animals have gathered at the top of the tube.

Why?

Is it because there is more air at the top of the tube?

Is it because there is more light at the top?

Is it because the animals move against the force of gravitation?

What can you do to find out?

There are many other kinds of behavior that you can observe and study in a drop of water. Here are a few.

How do different animals in the pond water culture catch their food?

How do different animals move about?

How do different animals avoid their enemies?

If you continue to watch the world in a drop of water under the microscope, you will surely think of questions of your own that you want answered. And you will think of ways to investigate your questions. You may find yourself wanting to read what other people have found out about something that interests you. You may find yourself wanting to talk with other people about something you have discovered, or something you want to try. Reading about things that interest them, finding out what other people have done, talking over how investigations might be done, swapping knowledge and ideas—these are things that scientists do when they are on the trail of something interesting.

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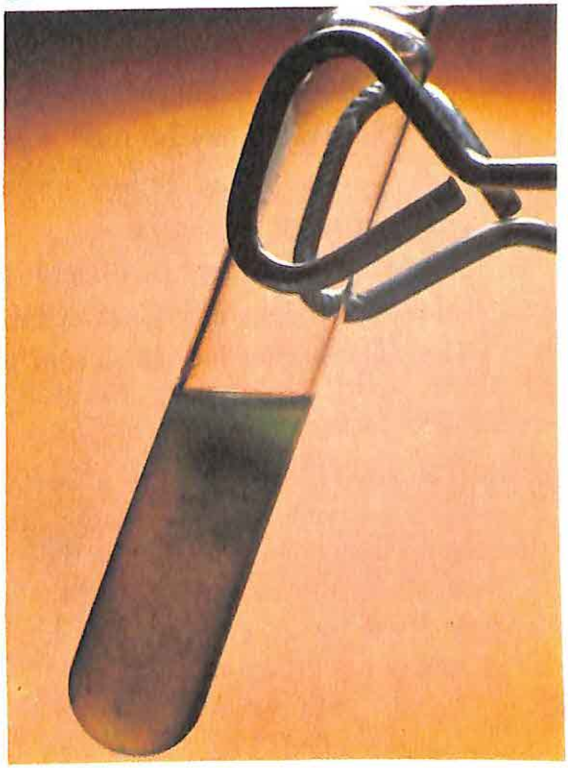

KEY CONCEPT WORDS: A BEGINNING VOCABULARY FOR SCIENCE

To record what they have learned from their investigations, scientists use words that have the same meaning to every other scientist. That is, scientists try to use words accurately. You are building up a vocabulary of key concept words of science during this year, which you will of course want to use correctly. The first time a word is used with a special meaning for scientific communication, it is in boldface type in your textbook. In this vocabulary of key concept words, a page reference is given to refer to if you need more information or examples of the meaning than is given here. In other words, the definition given here is a short, first definition that needs filling out. The complete meaning of the word cannot be given here as you need more work in science for full understanding. A few terms you probably know from earlier work in science do not have a page reference; you already know how to use these words in their correct meaning. The words may be used a number of times in this textbook; the Index will help you see how these words are used accurately throughout your work in science.

Words that may be difficult to pronounce are respelled in parentheses after the word. Each syllable is pronounced just as it is spelled. The syllable that has the accent is in capital letters.

absorb (ab·ZORB), to take up a substance, as a sponge takes up water, or to take up molecules and change their movement, as in a sound wave, 24

adapted, fitted by its structure for life in a certain environment, 165

algae (AL·jee), tiny green plants, generally single-celled, 179

atmosphere (AT·mus.feer), the layer of gases around the Earth, the air, 272

atom, a building block of elements; atoms combine chemically to build molecules, 105

bacteria (bak·TEER.ee.uh), tiny plants that can be seen only with a strong microscope; they have only a single cell and no green coloring matter, 90

behavior (beh·HAYV·yur), the way a living thing responds to its environment, 204

carbohydrate (KAHR·boh·hy·drayt), a compound of carbon, hydrogen, and oxygen; it has twice as many hydrogen atoms as oxygen atoms. Any sugar or starch made by green plants, 149

cell, the smallest living unit of any living thing, 154

cell division, the dividing of a cell to make two new cells that are alike, 155

chemical change, a change in the make-up of a substance; in a chemical change, the atoms of the original substance are combined in a different way, 44

chemical reaction (KEM·ih·kul ree·AK·sh'n), the chemical change in which a compound is broken down into other substances, or is built up from other substances, 122

chlorophyll (KLOR·uh·fil), a substance in the cells of green plants which enables them to make sugars, 160

combine (kum·BYN), to join with, as iron and oxygen molecules join to form iron oxide, 105

comet (KOM·it), a body in space traveling in a long orbit around the Sun; it has a head and tail of matter that glow when the comet is near the Sun, 259

compound, a substance made up of atoms of two or more different elements, 108

condense, to change from a gas to a liquid. In **condensation,** loss of heat energy makes invisible gas molecules move closer together and form visible liquid, 68

confirm, to test a possible explanation to find if it is correct, as to test a theory, 115

constellation (KON·stel·lay·sh'n), a group of stars having a fixed pattern in a part of the sky.

contract (kon·TRAKT), to move closer together and take up less space. In **contraction,** molecules move closer together, 71. Muscle cells also contract.

convex lens, a lens that is thicker at the center than at the edges; it focuses light, 40

cover (kuv·OR), plants, leaves, grass, or other things that keep soil from being washed away by rain, 240

crust, the solid outside layer of the Earth, 246

current (KUR·ent), a flowing of a substance in a certain direction, as ocean currents or air currents, 80

decay, to become broken down into simpler substances. Wood and other substances decay and become humus, 161

diffused (dih·FYOOZ), reflected (spread out) in all directions, 33

displace, to take the place of. In the **displacement method** of collecting a gas, gas forced through water in a bottle takes the place of the water, 100

dissolve (dih·ZOLV), to mix completely in a liquid, as salt or oxygen in water, 83

echo (EK·oh), a sound wave that has bounced back to its source, as to the person who caused the sound wave to be sent out, 21

egg, a cell produced by a female organism. When sperm from a male unites with it, the egg is fertilized and can grow into a new organism, 184

element (EL.ih.ment), a substance made up of only one kind of atom, 108

ellipse (ih.LIPS), a line or path, oval in shape, like a circle flattened on opposite sides, 264

embryo (EM.bree.oh), a young living animal as it forms inside an egg, or a young living plant inside a seed, 198

energy, the ability to do work; that is, to make matter move, 38

environment (en.VY.ron.ment), all the things and conditions around the place where a plant or animal lives, 137

evaporate (ih.VAP.uh.rayt), to change from a liquid to a gas. In **evaporation,** molecules of the liquid escape and mix with air. Heat energy makes the molecules of the liquid move farther apart, 64

expand (ik.SPAND), to move farther apart and take up more space. In **expansion,** molecules move farther apart, 71

fat, a compound of carbon, hydrogen, and oxygen; fat molecules have a higher proportion of carbon and hydrogen atoms, and fewer oxygen atoms, than do starch and sugar molecules, 149

fertilizer (FUR.til.i.zer), a substance added to the soil to replace compounds taken from the soil by growing plants, 144

fish ladder, a series of small falls and pools that help salmon go up a river, past high dams built by man, 183

focus (FOH.kus), to bring to a point, as to focus light, 40

food chain, an interrelationship between a plant or animal and its source of energy; each food chain leads to a green plant which captures the energy of sunlight, 180

force, a push or pull. A force may make something move, 226

friction, a force at the surface of an object that makes it hard to move another object across it. Friction causes heat when objects are rubbed together, 272

full moon, the time when the Moon is on the side of the Earth opposite the Sun, 258

fungi (FUN.jy), *singular* **fungus** (FUN-gus) plants, such as bread mold or yeast, that cannot make their own food; they have no chlorophyll, 158

gas, any substance that spreads out to fill the container it is placed in. Molecules are far apart and each molecule can move freely, 17

gill (gil), a structure in a fish that enables it to take in oxygen dissolved in water, 192

glacier (GLAY.shur), a moving river of ice, 83

gravitation (grav.ih.TAY.sh'n), the pull every object in space has on every other object; for example, the pull the Earth has on an object, 265

habitat (HAB.ih.tat), the special environment of a living thing, 189

half moon, the time when the Moon is to one side of the Earth's orbit around the Sun, 258

humus (HYOO·mus), bits of decayed plants and animals in soil, 161

hypothesis (hy·POTH·eh·sis), an explanation of an event, which is meant to be tested by investigation, 115

inborn, within a living thing at birth. Some behavior may be inborn, 204

lens, a piece of glass shaped in a special way to bend rays of light, 40

liquid (LIK·wid), any substance that pours and changes shape to fit the part of the container into which it is poured. Molecules in a liquid can move easily, 17

matter, anything that has weight and takes up space

membrane, thin skin around an egg or a cell, 198

meteor (MEE·tee·or), a burning piece of rock from space that glows as it becomes heated from friction when it passes through the layer of air around the Earth, 270

meteorite (MEE·tee·uh·ryt), a piece of rock from space that reaches the Earth before completely burning up in the atmosphere, 273

microscope (MY·kra·scohp), a tool which magnifies objects and makes them seem much larger than they are

migration (my·GRAY·sh'n), the traveling back and forth of certain living things. Wild ducks migrate south in the fall, and come north again in the spring, 201

model (MOD·l), something designed or built to help a person understand or explain an object or event, 50

molecule (MOL·eh·kyool), smallest part there can be of any substance without its being changed, 15

mouth, the place where a river meets the sea, 238

new moon, the time when the Moon and Sun are on the same side of the Earth, 258

nitrate (NY·trayt), a compound of nitrogen and oxygen needed by green plants for good growth, 142

orbit (OR·bit), the path of one object in space around another, as that of the Moon around the Earth, 258

oxygen cycle, the change of oxygen to carbon dioxide by animals, the use of carbon dioxide by plants, the giving back of oxygen by plants, and its use again by animals, 126

phosphate (FOS·fayt), a compound of phosphorus and oxygen needed by green plants for good growth, 142

pitch, highness or lowness of a sound, 8

polarized (POH·luh·riz'd), allowing light waves to pass through up and down or from side to side, but not in both ways at the same time, 50

pressure (PRESH·shur), a steady push against an inside or outside surface, 111

protein (PROH·tee·in), a compound of carbon, hydrogen, oxygen, and nitrogen, and often of sulfur and phosphorus, 149

protozoan (proh·teh·ZOH·en), a tiny single-celled animal, 179

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